Draft CALPUFF BART Modeling Protocol
For Federal Mandatory Class I Areas

DRAFT

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LIST OF ABBREVIATIONS

Δ	Symbol For Change
$\mu g/m^3$	Micrograms Per Cubic Meter
b_{abs}	Absorption Gases and Particles
b_{ag}	Light Absorption of Gases
b_{ap}	Light Absorption of Particles (Elemental Carbon)
BART	Best Available Retrofit Technology
b_{Coarse}	Coarse Particles
b_{ext}	Light Extinction Coefficient
BLM	Bureau of Land Management
b_{NO3}	Ammonium Nitrate, $(NH_4)NO_3$
b_{OC}	Total Organic Aerosols
b_{ray}	Rayleigh Scattering
b_{scat}	Scattering Gases and Particles
b_{sg}	Light Scattering of Gases
b_{SO4}	Ammonium Sulfate, $(NH_4)_2SO_2$
b_{SOIL}	Fine Particles
b_{sp}	Light Scattering of Particles
C	Centigrade
dv	Deciviews
EC	Elemental Carbon
EPA	U.S. Environmental Protection Agency
exp	Exponential
F	Fahrenheit
f(RH)	Relative Humidity Adjustment Factor
FLAG	Federal Land Managers AQRV (Air Quality Related Values) Workgroup
ft	Feet
ft/sec	Feet Per Second

LIST OF ABBREVIATIONS (continued)

FWS	U.S. Fish and Wildlife Service
g/sec	Gram(s)/Second
IMPROVE	Interagency Monitoring of Protected Visual Environments
IWAQM	Interagency Workgroup on Air Quality Modeling
K	Kelvin
K	Koschmieder Coefficient, unitless, ranges from 3.0 to 3.9
km	Kilometer(s)
lb/day	Pounds Per Day
LCC	Lambert Conformal Conic
ln	Natural Logarithm
m	Meter(s)
m^2/g	Meter Squared Per Gram
m/sec	Meters Per Second
MDEQ	Montana Department of Environmental Quality
Met	Meteorological
Mm^{-1}	Inverse Megameters
MM4	Fourth Generation Three-Dimensional Mesoscale Weather Prediction Model Developed Penn State/NCAR
MM5	Fifth Generation Three-Dimensional Mesoscale Weather Prediction Model Developed Penn State/NCAR
NAD27	North American Datum 1927
NAD83	North American Datum 1983
NEI	EPA National Emission Inventory
NO_2	Nitrogen Dioxide
NO_3	Nitrates
NOAA	National Oceanic and Atmospheric Administration
NO_X	Nitrogen Oxides
NP	National Park
NPS	National Park Service

LIST OF ABBREVIATIONS (continued)

PM_{10}	Particulate Matter Less Than Or To Equal 10 Microns
$PM_{2.5}$	Particulate Matter Less Than Or To Equal 2.5 Microns
ppb	Parts Per Billion
QA/QC	Quality Assurance/Quality Control
SO_2	Sulfur Dioxide
SO_4	Sulfates
tons/day	Tons Per Day
tpy	Tons Per Year
USDA-FS	U.S. Department of Agriculture - Forest Service
USDI-NPS	U.S. Department of Interior - National Park Service
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
UTM(s)	Universe Transverse Mercator
VIEWS	Visibility Information Exchange Web System
VR	Visual Range
WA	Wilderness Area
WRAP	Western Regional Air Partnership

DEFINITIONS

“BART-eligible source” means an existing stationary facility, which emits visibility-impairing pollutant in amounts the Montana Department of Environmental Quality anticipates will cause or contribute to any visibility impairment in any mandatory federal Class I area.

"Best Available Retrofit Technology (BART)" means an emission limitation based on the degree of reduction achievable through the application of the best system of continuous emission reduction for each pollutant, which is emitted by an existing stationary facility. The emission limitation must be established on a case-by-case basis, taking into account the following factors: available technology, the cost of compliance, the energy and non-air quality environmental impacts of compliance, any pollution control equipment in use or in existence at the source, the remaining useful life of the source and the degree of improvement in visibility, which may reasonably be anticipated to result from the use of such technology.

“Deciview” means a measurement of visibility impairment. A deciview is a haze index derived from calculated light extinction, such that uniform changes in haziness correspond to uniform incremental changes in perception across the entire range of conditions, from pristine to highly impaired. The deciview haze index is calculated based on the following equation (for the purposes of calculating deciview, the atmospheric light extinction coefficient must be calculated from aerosol measurements):

Deciview haze index = $10 \ln (b_{ext}/10 \text{ Mm}^{-1})$.

Where b_{ext} = the atmospheric light extinction coefficient, expressed in inverse megameters (Mm^{-1}).

“Existing stationary facility” means any of the following stationary sources of air pollutants, including any reconstructed source, which was not in operation prior to August 7, 1962, and was in existence on August 7, 1077, and has the potential to emit 250 tops per year or more of any air pollutant. In determining potential to emit, fugitive emissions, to the extent quantifiable, must be counted.

- fossil-fuel fired steam electric plants of more than 250 million British thermal units per hour heat input
- coal cleaning plants (thermal dryers)
- kraft pulp mills
- Portland cement plants
- primary zinc smelters
- iron and steel mill plants
- primary aluminum ore reduction plants
- primary copper smelters
- municipal incinerators capable of charging more than 250 tons of refuse per day
- hydrofluoric, sulfuric, and nitric acid plants
- petroleum refineries
- lime plants

- phosphate rock processing plants
- coke oven batteries
- sulfur recovery plants
- carbon black plants (furnace process)
- primary lead smelters
- fuel conversion plants
- sintering plants
- secondary metal production facilities
- chemical process plants
- fossil-fuel boilers of more than 250 million British thermal units per hour heat input
- petroleum storage and transfer facilities with a capacity exceeding 300,000 barrels
- taconite ore processing facilities
- glass fiber processing plants
- charcoal production facilities

"Federal Land Manager (FLM)" means the Secretary of the Department with authority over a given Federal Class I area. The FLM for the Department of the Interior is the Assistant Secretary for Fish and Wildlife and Parks; the FLM for the Department of Agriculture is the Forest Service, through the Regional Forester or individual Forest Supervisor.

"Federal Mandatory Class I Area" means certain national parks and wilderness areas over 6,000 acres and 5,000 acres respectively in existence on August 7, 1977, established by Congress, where visibility has been determined to be an important value. These areas are defined in 40 CFR 81.417.

"Fixed capital costs" means the capital needed to provide all of the depreciable components.

"Fugitive emissions" means those emissions, which could not reasonably pass through a stack, chimney, vent, or other functionally equivalent opening.

"In existence" means that the owner or operator has obtained all necessary preconstruction approvals or permits required by federal, state, or local air pollution emissions and air quality laws or regulations and either has begun, or caused to begin, a continuous program of physical on-site construction of the facility; or entered into binding agreements or contractual obligations, which cannot be canceled or modified without substantial loss to the owner or operator, to undertake a program of construction of the facility to be completed in a reasonable time.

"In operation" means engaged in activity related to the primary design function of the source.

"Installation" means an identifiable piece of process equipment.

“Natural conditions” includes naturally occurring phenomena that reduce visibility as measured in terms of light extinction, visual range, contrast, or coloration. These phenomena include fog, clouds, wind blown dust, rain, sand, naturally ignited wildfires and natural aerosols.

"Potential to emit" means the maximum capacity of a stationary source to emit a pollutant under its physical and operational design. Any physical or operational limitation on the capacity of the source to emit a pollutant including air pollution control equipment and restrictions on hours of operation or on the type or amount of material combusted, stored, or processed, shall be treated as part of its design if the limitation or the effect it would have on emissions is federally enforceable. Secondary emissions do not count in determining the potential to emit of a stationary source.

“Reasonably Attributable” means visibility impairment in a Class I area caused by emissions from one or a small group of sources generally located in close proximity to the Class I area.

“Reconstruction” will be presumed to have taken place where the fixed capital cost of the new component exceeds 50 percent of the fixed capital cost of a comparable entirely new source. Any final decision as to whether reconstruction has occurred shall be made in accordance with 40 CFR §60.15.

“Regional Haze” means visibility impairment in one or several Class I areas caused by emissions from numerous anthropogenic sources located over a wide geographic area.

“Secondary emissions” means emissions, which occur as a result of the construction or operation of an existing stationary facility but do not come from the existing stationary facility. Secondary emission may include, but are not limited to, emission from ships or trains coming to or from the existing stationary facility.

"Stationary source" means any building, structure, facility, or installation, which emits or may emit any air pollutant.

"Visibility impairment" means any humanly perceptible change in visibility (light extinction, visual range, contrast, coloration) from that which would have existed under natural conditions.

1.0 INTRODUCTION

On July 1, 1999, the U.S. Environmental Protection Agency (EPA) published the final rule of the regional haze regulations (64 FR 35714, July 1, 1999). The objective of the federal regional haze regulations is to improve visibility in 156 specific areas across United States, known as "Class I" areas. The Clean Air Act defines federal mandatory Class I areas as certain national parks (over 6000 acres), wilderness areas (over 5000 acres), national memorial parks (over 5000 acres), and international parks that were in existence on August 7, 1977 as defined in 40 CFR 81.417.[1]

States are required to conduct certain analyses to ensure reaching natural visibility conditions in 60 years (from 2004 to 2064). To measure progress toward this goal, the regional haze program requires that a comparison with natural conditions for the 20% best visibility days and use the 20% worst visibility days to calculate ``reasonable progress''. Overall, States must establish goals:

1) to improve the visibility on the 20% haziest days and

2) to ensure no degradation occurs on the 20% cleanest days over the implementation planning period.

The first long-term strategy will cover 10 to 15 years with reassessments and revisions of those goals and strategies in 2018 and every 10 years thereafter. A midterm analysis will be conducted around 2013. State strategies should also address their contribution to visibility problems in federal mandatory Class I areas both within and outside the State boundaries due to the long-distance transport of air pollutants that cause haze.

On July 6, 2005, the EPA published the final amendments to its 1999 regional haze rule in the Federal Register providing the final guidance for Best Available Retrofit Technology (BART) determinations including Appendix Y, (70 FR 39104-39172).[2] The BART rule requires the installation of BART ("subject-to-BART") on industrial emission sources that fit specific criteria and "anticipated to cause or contribute to visibility impairment in any federal mandatory Class I area."

The Montana Department of Environmental Quality (MDEQ) is primarily responsible for the BART process. The MDEQ will identify those sources that meet the definition of "BART-eligible source" as defined in 40 CFR 51.031, with assistance from the owner or operator of such source(s). Then the MDEQ will determine whether a BART-eligible source is subject to BART. The MDEQ has proposed a state regulation establishing a "contribution threshold" of 0.5 deciviews (dv). This is a change in visibility (delta-

1. 40 CFR 81. Subpart D – Identification of Mandatory Class I Federal Areas Where Visibility Is an Important Value. Revised July 1, 2003.

2. Federal Register. 2005. EPA Regional Haze Regulations and Guidelines for Best Available Retrofit Technology (BART) Determinations; Final Rule. Federal Register. July 6, 2005. Vol. 70. No. 128. p. 39103-39172.

deciview, Δ dv) caused by the emissions from a BART-eligible source(s) relative to the natural background visibility conditions at a federally mandated Class I area.

There are twelve federal mandatory Class I areas in Montana. Four other federal mandatory Class I areas in neighboring states will also be included in the BART analysis since Montana BART-eligible sources may affect these areas. All sixteen federal mandatory Class I areas of concern are listed in Table 1.0A.

Table 1.0A: Sixteen Significant Federal Mandatory Class I Areas.

Montana Class I Areas	**Class I Areas in Neighboring States**
Anaconda-Pintler Wilderness Area	North Absaroka Wilderness Area – Wyoming
Bob Marshall Wilderness Area	Selway-Bitterroot Wilderness Area – Idaho
Cabinet Mountains Wilderness Area	Theodore Roosevelt National Park - North Dakota
Gates of the Mountains Wilderness Area	Yellowstone National Park – Wyoming
Glacier National Park	
Medicine Lake Wilderness Area	
Mission Mountains Wilderness Area	
Red Rock Lakes Wilderness Area	
Scapegoat Wilderness Area	
Selway-Bitterroot Wilderness Area	
U.L. Bend Wilderness Area	
Yellowstone National Park	

As of February 2006, the MDEQ has identified ten facilities that may possess BART-eligible sources; Table 1.0B lists these facilities.

Table 1.0B: Ten Montana Facilities With Potential BART-Eligible Sources.

Facility	**Facility**
ASARCO Incorporated	Holcim – Trident Plant
Ash Grove Cement Company – Montana City	Montana Sulphur & Chemical Company
CHS Inc. (formerly Cenex Harvest States Cooperatives) – Laurel	PPL Montana, LLC – Corette Plant
Columbia Falls Aluminum LLC	PPL Montana, LLC – Colstrip 1 & 2
Exxon Mobil Corporation – Billings Refinery	Smurfit-Stone Container Enterprises, Inc. – Missoula

All federally mandated Class I areas within 300 kilometers (km) of the potential BART-eligible source(s) will be included in the modeling analysis for that source(s). Figure 1.0A displays the modeling domain with the federal mandatory Class I areas of concern and Figure 1.0B shows the facilities that possess potential BART-eligible sources in the same modeling domain.

Figure 1.0A: Montana BART Modeling Domain and Federal Mandatory Class I Areas

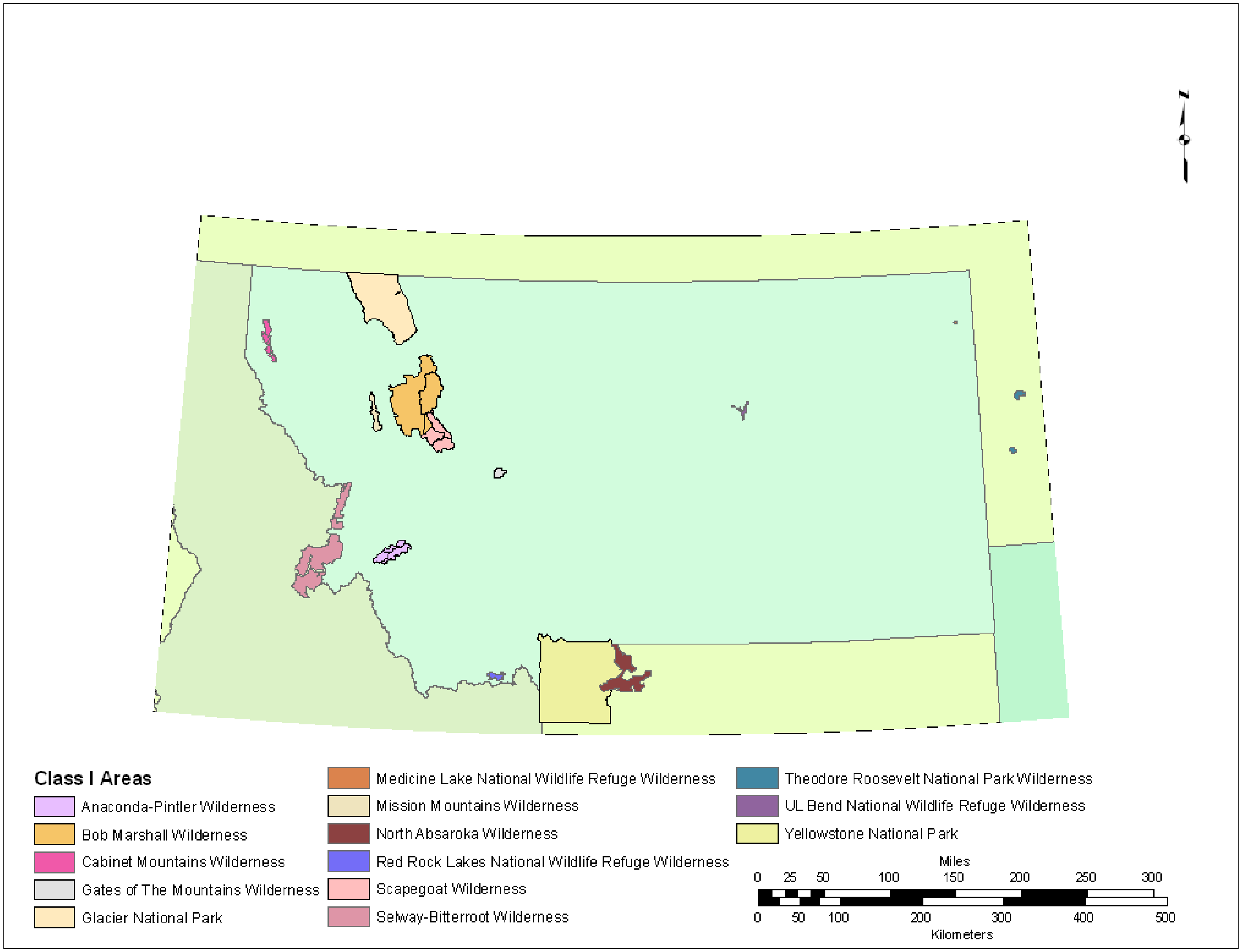
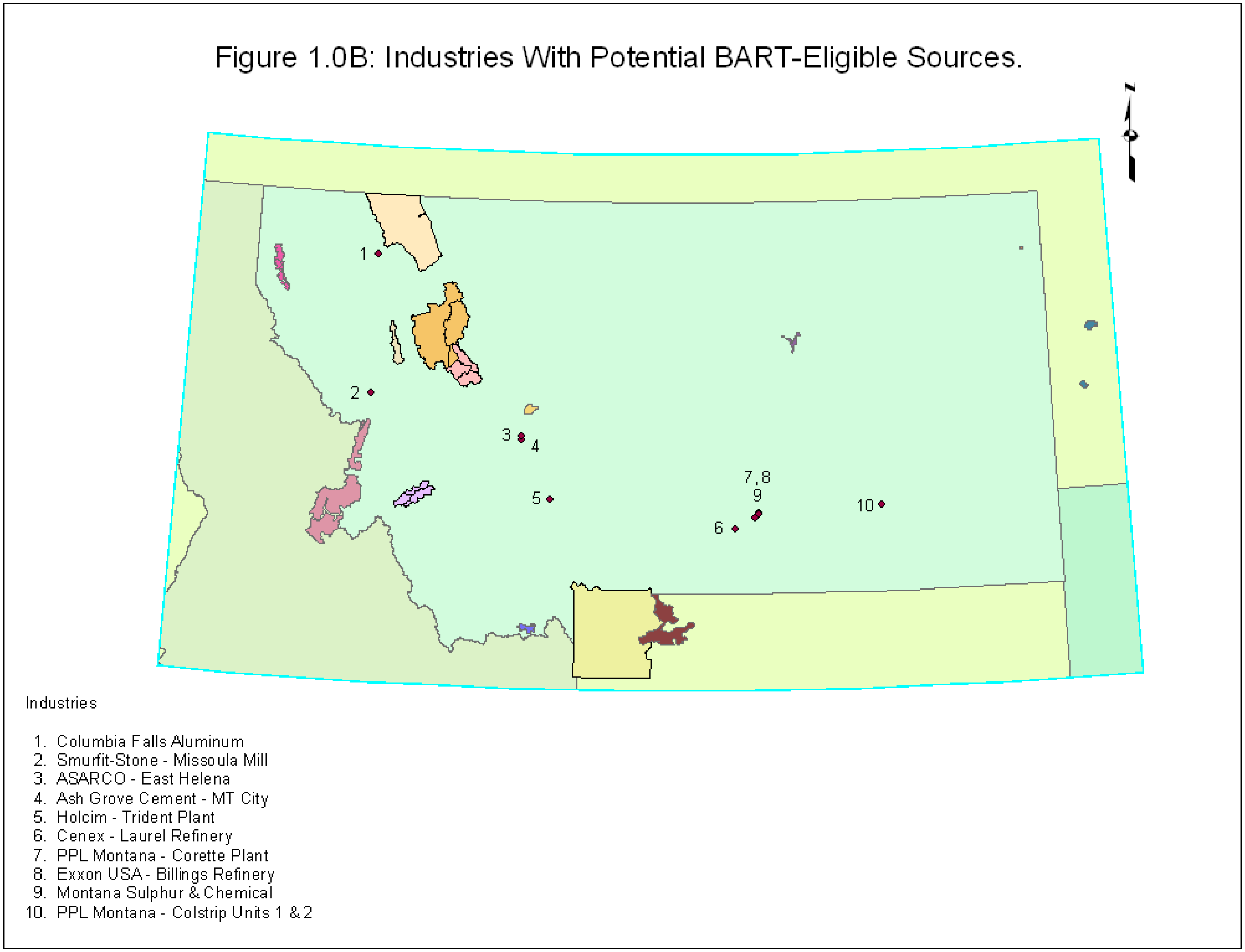


Figure 1.0B: Montana Industries With Potential BART-Eligible Sources.



The MDEQ will use the Professional CALPUFF (Version 2.18.0) by Bee-Line Software as the CALPUFF platform. This software, also known as CALPUFFPRO, interfaces with Earth Tech CALPUFF, but simplifies the process and produces excellent graphics.

The modeling process is essentially three-fold: "BART-eligible", "subject-to-BART", and effect(s) of BART. In all cases, the CALPUFF computer will be used with three years of meteorological data as recommended by the BART guidelines. In this analysis, the years 2001 through 2003 will be used. Emissions of the following air pollutants will be addressed: sulfur dioxide (SO_2), nitrogen oxides (NO_X), and particulate matter less than or to equal 10 microns (PM_{10}). Any mandatory federal Class I area within 300 kilometers (km) of the source(s) to be modeled will be included to determine the impacts of the emissions on the area's visibility.

BART-Eligible Modeling

The first step is referred to as "BART-eligible" modeling analysis. All SO_2, NO_x, and PM_{10} emissions from all of the BART-eligible sources at a given facility will be modeled together.

The emission rates will be the maximum steady-state 24-hour actual emissions (ignoring periods of startup, shutdown, and malfunction) produced under maximum production achieved during a calendar year within the 2001 to 2003 time period. If the emissions during this period do not represent maximum capacity, the maximum 24-hour actual emission rates will be obtained from another recent year. The MDEQ will review all emission rates for accuracy.

As stated previously, the MDEQ will apply the CALPUFF computer model with three years of meteorological data. All Class I areas within 300 kilometers (km) of the facility with the BART-eligible source(s) will be included in the modeling analysis. The model will calculate the number of days with a delta-deciview (Δ dv) greater than or equal to 0.5 dv (contribution threshold) for each met year. If the daily 98th percentile value for any year or all met years combined is greater than this contribution threshold, then the source (or sources) is considered "subject-to-BART".

For clarification, the EPA recommends calculating the 98th percentile value for one met year as the value on the 8th highest day (8 days/365 total days * 100 ≈ 2% ≈ 98th percentile). Combining all three years of met data, the 98th percentile value would be the value on the 22nd highest day (22/(365+365+365)) * 100 ≈ 2% ≈ 98th percentile). The greater of the two values will be selected for comparison to the 0.5 dv contribution threshold. If the selected Δ dv value is greater than 0.5 dv, the BART-eligible unit(s) is considered subject-to-BART and a second round of modeling.

BART-Subject Modeling

The MDEQ will again apply the CALPUFF computer model with the same meteorological dataset, but each subject-to-BART source (or "unit") will be modeled individually on an individual air pollutant basis (SO_2, NO_X, and PM_{10}, where applicable). Again, all Class I areas within 300 kilometers (km) of the individual subject-to-BART source will be included in the modeling analysis for that source. The CALPUFF model will calculate the Δ dv contribution for each source on a pollutant basis for each met year. The MDEQ will track the daily 98th percentile values for the BART determination process and provide this data to the owner or operator of the BART-subject source(s).

This modeling scenario is considered the "base case" (before BART) for that source so that the results from subsequent modeling with BART (post-BART) can be attributed to the BART emissions reductions. Some emissions control technologies can increase the emissions of another air pollutant of concern; therefore, all air pollutant emissions will be checked post-BART.

The owner or operator of the BART-subject source(s) will perform this BART determination analysis considering the following five factors:

- existing control technology in place at the source;
- costs of compliance;
- energy and non-air environmental impacts of compliance;
- remaining useful life of the source; and
- the degree of visibility improvement that is reasonably anticipated from the use of such technology.

<u>BART Results Modeling</u>

After the MDEQ has concurred with the BART analysis, the MDEQ will conduct the third CALPUFF modeling demonstration identical to the base case except with the BART control technology (or technologies) installed. Each subject-to-BART source or "unit" within a facility will be modeled individually on an individual air pollutant basis. The 98th percentile value of the 24-hour change in visibility will once more be compared to the 0.5 dv threshold.

The MDEQ heavily emphasizes that this is a draft BART modeling protocol, not a BART determination protocol. The operators or owners of the BART-subject source(s) are responsible for the BART determinations. The MDEQ will review the determinations on a case-by-case basis, and issue a notice of determination.

The MDEQ will release this draft BART modeling protocol for a 30-day public comment period. The MDEQ will use this draft protocol for the initial subject-to-BART modeling analysis. Subsequent modeling performed by the MDEQ may supersede those results.

The latest modeling techniques will be applied that are consistent with the EPA and federal land managers' recommendations, and BART guidelines.[2] The MDEQ may approved deviations from this protocol for a specific source that are documented in a modeling protocol and accepted by the EPA if the model performance is improved while retaining consistency with the BART guidelines. All modeling analyses will be subject to MDEQ review and approval.

Furthermore, the contribution threshold and other criteria used for the BART modeling have not been finalized and may change in the final rule adopted by the Montana Board of Environmental Review. Therefore, the modeling results performed with this protocol are not a final agency action. Any source that the MDEQ determines is subject-to-BART will receive a separate notice of the department's final determination.

The MDEQ expects to post all input and output files relating to the CALPUFF modeling including any software updates that become available on the MDEQ CALPUFF Visibility web site, which is currently under development. For consistency, the MDEQ highly recommends these files be used for BART-related modeling by the owner or operator of the potential BART-eligible/subject source(s).

2.0 VISIBILITY CALCULATIONS

Visibility monitoring in national parks and wilderness areas is conducted through the Interagency Monitoring of Protected Visual Environments (IMPROVE) program. Participants are representatives from the National Park Service (NPS), U.S. Forest Service (USFS), Bureau of Land Management (BLM), U.S. Fish and Wildlife Service (FWS), EPA, and regional-state organizations. The IMPROVE program includes the characterization of haze by photography, the measurement of light extinction with specialized instruments (such as transmissometers and nephelometers), and the measurement of the composition and concentrations of fine particles that produce haze. Fine particle concentrations is the focus of the regional haze program and therein, the BART modeling analysis.

The light extinction coefficient (b_{ext}) has generally been used in the U.S. for many years to describe visibility and the change in visibility due to changes in the concentrations of air pollutants. The light extinction coefficient is also related to the visual range, the greatest distance that an observer can just see a black object viewed against the horizon sky.

In the following equation, the visual range (VR) is measured in kilometers (km) and K is the Koschmieder coefficient, which ranges from 3.0 to 3.9. This unitless coefficient is the natural log of the contrast threshold of the human eye. For regional haze, K equals 3.912, which is often truncated to 3.910, and the light extinction coefficient has units of inverse megameters (Mm^{-1}).

$$VR = K/b_{ext} \rightarrow VR\ (km) = 3.912/\ b_{ext}\ (Mm^{-1})$$

With rearrangement, the equation converts to:

$$b_{ext}\ (Mm^{-1}) = 3.912/VR\ (km)$$

Visibility is measured in deciviews (dv). The scale of this visibility index is linear so a change of 1.0 deciview (more precisely, 0.9531 dv) represents approximately a 10%

change in b_{ext}, which is noticeable by most observers under most visibility conditions. The relationship between the light extinction coefficient and deciview is expressed in the following equation.

$$b_{ext}\ (Mm^{-1}) = 10 \exp (dv/10\ Mm^{-1})$$

(exp = exponential)

or

$$dv = 10 \ln (b_{ext}\ Mm^{-1}/10\ Mm^{-1})$$

(ln = natural logarithm)

Visibility is impaired by scattering (b_{scat}) and absorption (b_{abs}) of atmospheric gases and particles.

$$b_{ext} = b_{scat} + b_{abs}$$

This equation can be further characterized by the following.

$$b_{ext} = b_{sg} + b_{ag} + b_{sp} + b_{ap}$$

where s, a, g, and p refer to scattering, absorption, gases, and particulates, respectively.

Light scattering due to air molecules (nitrogen and oxygen molecules) is called Rayleigh scattering (b_{ray}). This component varies slightly due to elevation and temperature; currently, the default value for b_{ray} is 10 Mm^{-1}. The light absorption component of extinction from gases (b_{ag}) is considered negligible. Therefore, the primary factors to visibility impairment are particle absorption (b_{ap}) and scattering (b_{sp}).

Scattering by particles (b_{sp}) has five main components as seen in following equation.

$$b_{sp} = b_{SO4} + b_{NO3} + b_{OC} + b_{SOIL} + b_{Coarse}$$

where

b_{SO4} = Ammonium Sulfate = 3 * f(RH) * [$(NH_4)_2SO_2$]

b_{NO3} = Ammonium Nitrate = 3 * f(RH) * [$(NH_4)NO_3$]

b_{OC} = Total Organic Aerosols = 4 * [OC]

b_{SOIL} = Fine Particles = 1 * [Soil]

b_{Coarse} = Coarse Particles = 0.6 * [Coarse Mass]

The numeric factors (i.e., 3) in the beginning of each term refer to the assumed dry scattering efficiencies in meter squared per gram (m^2/g). The values in the brackets are concentrations in micrograms per cubic meter ($\mu g/m^3$). The f(RH) term is the relative humidity adjustment factor, which accounts for the fact that sulfate and nitrate particles grow under high relative humidity conditions. Appendix A shows values of f(RH) determined from the growth of ammonium sulfate.

The final variable is particle absorption (b_{ap}). Elemental carbon (EC) or soot is the primary source of particle absorption in the atmosphere and is defined below.

$$b_{ap} = \text{Elemental Carbon} = 10 * [EC]$$

The numeric factor (i.e., 10) refers to the assumed dry absorption efficiency in meter squared per gram (m^2/g). The final IMPROVE equation to estimate the total reconstructed light extinction in the atmosphere is summarized below.

$$b_{ext} = b_{SO4} + b_{NO3} + b_{OC} + b_{SOIL} + b_{Coarse} + b_{EC} + b_{ray}$$

b_{SO4} = Ammonium Sulfate = 3 * f(RH) * [$(NH_4)_2SO_2$]
b_{NO3} = Ammonium Nitrate = 3 * f(RH) * [$(NH_4)NO_3$]
b_{OC} = Total Organic Aerosols = 4 * [OC]
b_{SOIL} = Fine Particles = 1 * [Soil]
b_{Coarse} = Coarse Particles = 0.6 * [Coarse Mass]
b_{ap} = Elemental Carbon = 10 * [EC]

To reiterate, the values in the brackets are concentrations in micrograms per cubic meter ($\mu g/m^3$) and the f(RH) term is the relative humidity adjustment factor. The units of the light extinction are Mm^{-1}.

This formula is currently used by the IMPROVE program to describe haze in national parks and wilderness areas (Class I areas). However, a new IMPROVE haze equation has been developed to correct inadequacies of the current formula. This new equation was approved by the IMPROVE steering committee in December 2005 and is expected to be officially released by the EPA in March 2006. The new algorithm to estimate the light extinction coefficient (b_{ext}) will include:

- a sea salt term;
- site-specific Rayleigh scattering based on elevation and temperature;
- a larger ratio of organic mass to organic carbon;
- the terms for sulfate, nitrate, and organic carbon are divided into two size distributions based on concentration and new f(RH) factors;
- and an additional concentration of nitrogen dioxide.

The following is a clarification of the terms associated with the new equation.

f_S = function of the small concentration of the specie
f_L = function of the large concentration of the specie
f_{SS} = function of sea salt

For [Total Sulfate] < 20 $\mu g/m^3$:
[Large Sulfate] = [Total Sulfate] * [Total Sulfate]

For [Total Sulfate] ≥ 20 μg/m^3:

[Large Sulfate] = [Total Sulfate]

[Small Sulfate] = [Total Sulfate] - [Large Sulfate]

The brackets are concentration values in micrograms per cubic meter (μg/m^3). The same splitting process is applied to nitrate and organic carbon components.

With this information, the new IMPROVE equation to reconstruct light extinction is defined below.

$$
\begin{aligned}
b_{ext} \approx\ & 2.2 * f_s(RH) * [\text{Small Sulfate}] + 4.8 * f_L(RH) * [\text{Large Sulfate}] \\
& + 2.4 * f_s(RH) * [\text{Small Nitrate}] + 5.1 * f_L(RH) * [\text{Large Nitrate}] \\
& + 2.8 * [\text{Small Organic Carbon}] + 6.1 * [\text{Large Organic Carbon}] \\
& + 10 * [\text{EC}] \\
& + 1 * [\text{Soil}] \\
& + 1.7 * f_{ss}(RH) * [\text{Sea Salt}] \\
& + 0.6 * [\text{Coarse Mass}] \\
& + \text{Rayleigh Scattering (Site-Specific)} \\
& + 0.33 * [\ NO_2\ (\text{ppb})]
\end{aligned}
$$

Again, the numeric factors (i.e., 2.2) in the beginning of each term refer to the assumed dry scattering or absorption efficiencies in meter squared per gram (m^2/g). The values in the brackets are concentrations in micrograms per cubic meter (μg/m^3). The f(RH) terms are the relative humidity adjustment factors.

The total concentrations of sulfates, nitrates, and organic carbon aerosols measured at the Montana IMPROVE (Class I) monitoring sites are predominantly less than 20 μg/m^3 so the process of splitting these components into the two categories will be unnecessary. Therefore, the application of this new IMPROVE equation will generally reduce the impact of these constituents on light extinction (the new coefficients are smaller than the corresponding coefficients in the old formula).

The site-specific Rayleigh scattering will not change significantly for Montana since the current default value, 10 Mm^{-1}, corresponds to 1.8 kilometers (about 5,900 feet) above sea level. In addition, it remains constant, regardless of the visibility conditions (hazy or clean) so this factor does not reflect what causes haze.

The last component, nitrogen dioxide (NO_2), is not measured at any of the Montana IMPROVE monitoring sites at this time. This information may be available in the future.

When comparing the estimated (calculated) extinction using the current IMPROVE equation and measured extinction by a nephelometer, the old IMPROVE equation generally underestimates light extinction on very hazy, dirty days and overestimates the extinction on very clean days. The new equation tends to reduce this bias.

After the EPA has officially recognized the new equation for light extinction (b_{ext}), all of the IMPROVE data will need to be recalculated including the 5-year visibility baseline conditions (2000 – 2004) that are used to estimate current visibility conditions at Class I areas. The natural background visibility levels for these areas will also need to be recalculated. In addition, all applicable regional haze program guidelines must incorporate the new IMPROVE equation. Unfortunately, the timeline for these actions is uncertain.

The EPA intends to support both equations so States can choose which formula most adequately represents the reconstructed light extinctions in their Class I areas. In addition, VIEWS will also support both algorithms for the near future. VIEWS (Visibility Information Exchange Web System) is the online database of air quality data to support the EPA regional haze program (http://vista.cira.colostate.edu/views/).

The WRAP (Western Regional Air Partnership) will also need to decide which reconstructed light extinction equation to use. The WRAP is assisting western States by producing technical information and coordinating regional planning in support of the federal regional program including BART. This organization also contracted preliminary regional haze modeling for the entire western state region. For the 2002 model base year, the major point source emissions data was obtained from the EPA National Emission Inventory (NEI). The WRAP is a voluntary organization of western states, tribes, and federal agencies (http://www.wrapair.org/index.html).

Long-distance transport of air pollution is an important factor in regional haze. Potential Montana BART-eligible/subject sources may affect federal mandatory Class I areas in neighboring states. Conversely, BART-eligible/subject sources in those states may affect the Class I areas in Montana. Therefore, if consensus through WRAP or interstate agreements is not established, the modeled visibility impacts at the same Class I area using different reconstructed light extinction equations would be different even using the same emission sources.

3.0 CALPUFF MODEL SYSTEM

As specified in the BART guidelines:

> "CALPUFF is the best regulatory modeling application currently available for predicting a single source's contribution to visibility impairment and is currently the only EPA-approved model for use in estimating single source pollutant concentrations resulting from the long-range transport of primary pollutants. It can also be used for some other purposes, such as the visibility assessments addressed in today's rule, to account for the chemical transformation of SO_2 and NO_x."

The main components of the CALPUFF modeling system are CALMET, CALPUFF, and CALPOST. CALMET is the meteorological model that generates hourly three-dimensional meteorological fields such as wind and temperature. CALPUFF simulates the non-steady state transport, dispersion, and chemical transformation of air pollutants emitted from a source in "puffs". Hourly concentrations and/or deposition flux values are calculated at each specified locations (receptors) in a modeling domain. For this visibility modeling analysis, two post-processing programs will be utilized the hourly concentrations: POSTUTIL and CALPOST. POSTUTIL will be used to implement the ammonia-limiting method to address double-counting of available ammonia for NO_x to NO_3 chemical conversion. Then the CALPOST post-processing program will be applied to compute the 24-hour basis light extinction coefficients from the hourly species concentrations at the selected locations.

Earth Tech (Earth Tech, Inc., Concord, MA), is the primary CALPUFF model developer and also provides several utility programs to accommodate pre-processing of meteorological and geophysical data for CALMET. The CALPUFF system software and user's guides can be downloaded from the Earth Tech web site (www.src.com/calpuff/calpuff1.htm).[3,4] The MDEQ will use the CALPUFF modeling versions listed in Table 3.0. However, if new and improved versions become available, the MDEQ will apply those versions and document the changes.

Table 3.0: CALPUFF Modeling System.

Program	Version	Level
CALMET	5.711	060107
CALPUFF	5.754	060202
POSTUTIL	1.43	060202
CALPOST	5.6393	060202

The MDEQ expects to post all input and output files relating to the CALPUFF modeling including any software updates that become available on the MDEQ CALPUFF Visibility web site, which is currently under development. For consistency, the MDEQ highly recommends these files be used for BART-related modeling by the owner or operator of the potential BART-eligible/subject source(s).

3.1 MODELING DOMAIN

The modeling domain will be sufficiently large to include the entire state of Montana and parts of four neighboring states: Idaho, North Dakota, South Dakota, and Wyoming. A segment of Canada is also included to complete the modeling domain (Figures 1.0A and B).

3. Earth Tech, Inc. 2000. A User's Guide for the Calmet Meteorological Model (Version 5). Earth Tech, Inc. Concord, MA 01742.
4. Earth Tech, Inc. 2000. A User's Guide for the Calpuff Dispersion Model (Version 5). Earth Tech, Inc. Concord, MA 01742.

The map projection will be Lambert Conformal Conic (LCC) and the coordinate system will be Montana State Plane NAD83 (North American Datum 1983), which is a LCC projection. The grid spacing will be 6 kilometers (km), but 1 km grid nesting will be created between one facility and a nearby Class I area. Columbia Falls Aluminum LLC is located just west of the Glacier National Park. In this case, the 1-km nested grids will increase the accuracy of the model.

The southwest corner of the modeling domain is Longitude 117.007 degrees west, Latitude 43.991343 degrees north, which equates to 0,0 in the Montana State Plane Coordinate System. The northeast corner of the modeling domain is approximately Longitude 103 degrees west, Latitude 49.5 degrees north.

According to the IWAQM, Phase 2 report:

> "CALPUFF is recommended for transport distances of 200 km or less. Use of CALPUFF for characterizing transport beyond 200 to 300 km should be done cautiously with an awareness of the likely problems involved."[5]

Since the modeling domain is significantly greater than 300 km (over 1,100 km in length), 300 km modeling subdomains will be created with the potential BART-eligible/subject source(s) essentially located in the center. Any Class I area that lies within these subdomain boundaries will be evaluated in that particular modeling demonstration.

3.2 CALMET INPUTS

The CALMET component of the CALPUFF modeling system is a complex model that requires detailed geophysical and meteorological data. Geophysical data includes terrain elevation, land use, and surface characteristics. Meteorological data contains surface and upper air data, and precipitation information.

3.3 GEOPHYSICAL INPUTS

The Bee-Line CalPuffPro software includes terrain and land use data. The terrain data is 3-arc second (approximately 90 meters) and land use data is 1:250,000 (250k) USGS (U.S. Geological Survey) data. Terrain data was unavailable for Canada so the terrain was extrapolated from the topography immediately to the south as shown in Figure 3.3A.

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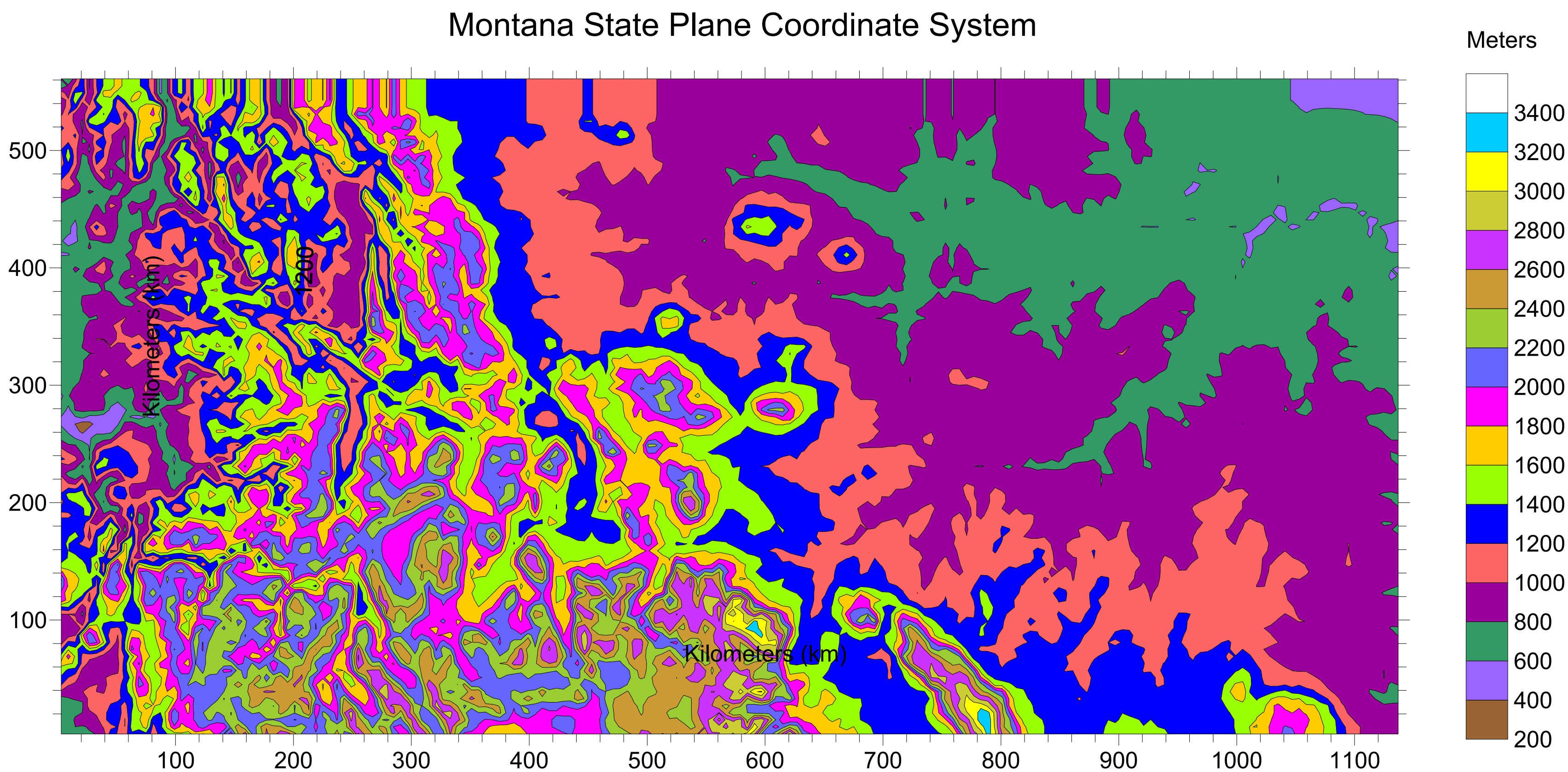
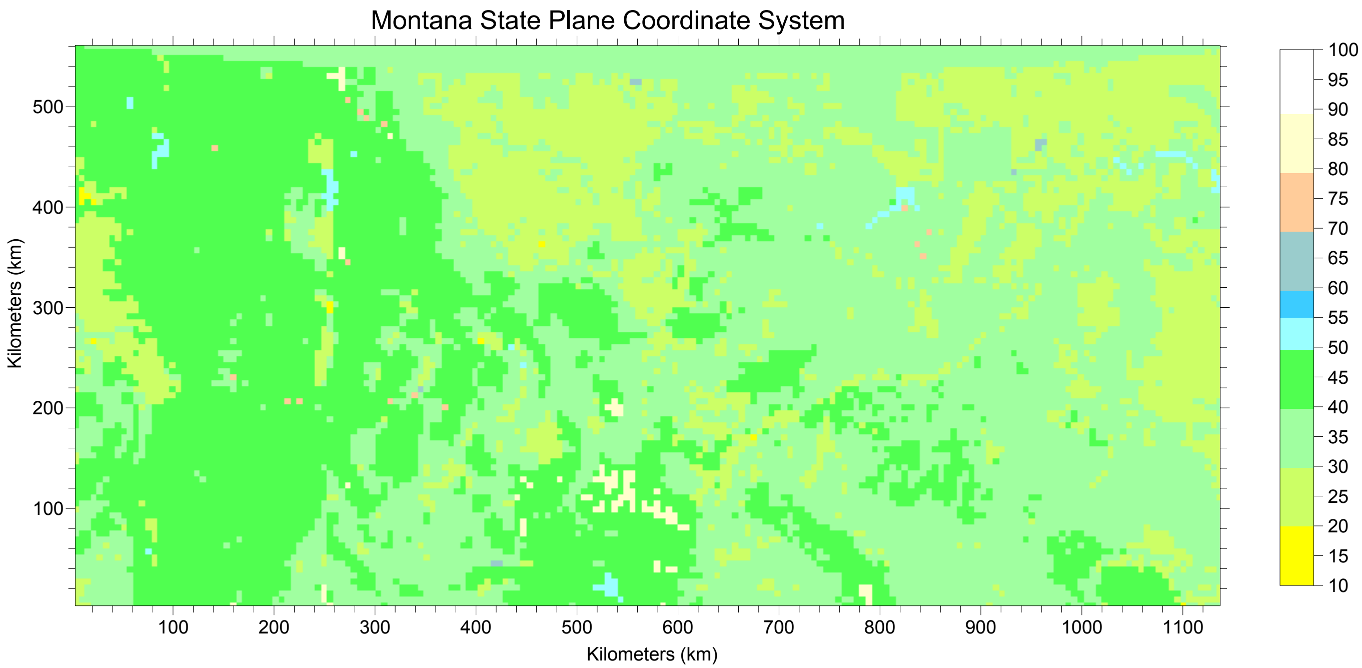
5. EPA. 1998. Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Report and Recommendations for Long-Range Transport Impacts. EPA-454/R-98-019. U.S. Environmental Protection Agency. Research Triangle Park, NC.

Figure 3.3A: Modeling Domain Terrain.



Land use data for Canada was also unavailable so for the following graphic, the land was assigned a mixed forest/rangeland land use type (33) as displayed in Figure 3.3B.

Figure 3.3B: Modeling Domain Land Use Categories.



Default CALMET Land Use Categories and Associated Geophysical Parameters
Based on the U.S. Geological Survey Land Use Classification System
(14-Category System)

Land Use Type	Description	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux Parameter	Anthropogenic Heat Flux (W/m^2)	Leaf Area Index
10	Urban or Built-up Land	1.0	0.18	1.5	.25	0.0	0.2
20	Agricultural Land - Unirrigated	0.25	0.15	1.0	.15	0.0	3.0
-20'	Agricultural Land - Irrigated	0.25	0.15	0.5	.15	0.0	3.0
30	Rangeland	0.05	0.25	1.0	.15	0.0	0.5
40	Forest Land	1.0	0.10	1.0	.15	0.0	7.0
51	Small Water Body	0.001	0.10	0.0	1.0	0.0	0.0
54	Bays and Estuaries	0.001	0.10	0.0	1.0	0.0	0.0
55	Large Water Body	0.001	0.10	0.0	1.0	0.0	0.0
60	Wetland	1.0	0.10	0.5	.25	0.0	2.0
61	Forested Wetland	1.0	0.1	0.5	0.25	0.0	2.0
62	Nonforested Wetland	0.2	0.1	0.1	0.25	0.0	1.0
70	Barren Land	0.05	0.30	1.0	.15	0.0	0.05
80	Tundra	.20	0.30	0.5	.15	0.0	0.0
90	Perennial Snow or Ice	.20	0.70	0.5	.15	0.0	0.0

' Negative values indicate "irrigated" land use

For the final BART modeling analysis corresponding to 2001 through 2003 met years, the land use data for Canada will be extrapolated from the land use data immediately to the south.

3.4 METEORLOGICAL INPUTS

As of February 2006, the WRAP Regional Modeling Center (University of California, Riverside, CA) has committed to deliver MM5 meteorological (met) data for the years 2001 through 2003 to the MDEQ. These hourly dataset were developed from fifth generation Penn State/NCAR three-dimensional mesoscale weather prediction model that produces wind fields on the same scale. The grids sizes will be 36 km for 2001 and 2003 met years, and 12 km for the year 2002, that will expand the entire modeling domain.

The National Park Service has supplied the MDEQ with 1996 MM5 meteorological dataset. To assess CALPUFF modeling intricacies, preliminary modeling will use this data until the other met data are available.

The surface/upper air and precipitation data will be acquired from the National Oceanic and Atmospheric Administration (NOAA) National Data Center. Hourly surface met data includes wind speed and direction, temperature, cloud cover, ceiling height, surface pressure, and relative humidity. Surface meteorological (met) data will also be obtained for two Canadian sites, Medicine Hat, Alberta and Estevan, Saskatchewan. Twice-daily upper air data contains wind speed and direction, temperature, pressure, and elevation. The hourly precipitation data contains the precipitation rates and precipitation type code associated with surface data files. Table 3.4A lists the thirty-one surface meteorological stations.

Table 3.4A: Surface Meteorological Stations.

Station	State/ Country	WBAN[a] ID	Station Code	Grid Coordinates		Coordinates[b]		Anemometer Height (m)	Time Zone
				X	Y	Latitude	Longitude		
Billings	MT	726770	BIL	673825	172705	45.808	108.54	10.00[c]	7
Butte	MT	726785	BTM	367559	193375	45.953	112.513	10.00[d]	7
Bozeman	MT	726797	BZN	471785	173608	45.794	111.152	10.00[d]	7
Cut Bank	MT	727796	CTB	388636	487259	48.608	112.376	10.00[d]	7
Dillon	MT	726796	DLN	360659	115806	45.255	112.552	10.00[d]	7
Glasgow	MT	727680	GGW	814110	444755	48.214	106.621	10.00[c]	7

Station	State/ Country	WBAN[a] ID	Station Code	Grid Coordinates		Coordinates[b]		Anemometer Height (m)	Time Zone
				X	Y	Latitude	Longitude		
Great Falls	MT	727750	GIF	458135	359171	47.473	111.382	10.00[c]	7
Havre	MT	727770	HVR	580293	477865	48.559	109.78	10.00[d]	7
Helena	MT	727720	HLN	411115	264112	46.606	111.964	10.00[c]	7
Kalispell	MT	727790	GPI	248045	462605	48.304	114.264	7.92[c]	7
Lewistown	MT	726776	LWT	603797	311134	47.049	109.467	10.06[c]	7
Livingston	MT	726798	LVM	526041	161595	45.699	110.448	10.00[d]	7
Miles City	MT	742300	MLS	877738	248998	46.428	105.886	10.00[d]	7
Missoula	MT	727730	MSO	250015	306636	46.921	114.093	10.00[c]	7
Boise	ID	726810	BOI	57389	-52671	43.565	116.22	10.00[c]	7
Coeur d'Alene	ID	727834	COE	52595	416389	47.679	116.802	10.00[d]	7
Pocatello	ID	725780	PIH	349171	-143363	42.92	112.571	10.00[c]	7
Rexburg	ID	726818	RXE	414869	-43649	43.834	111.881	10.00[d]	7
Salmon	ID	726865	SMN	255322	106013	45.074	113.529	10.00[d]	7
Bismarck	ND	727640	BIS	1266552	317294	46.774	100.748	10.00[c]	6
Dickinson	ND	727645	DIK	1110543	305206	46.797	102.802	10.00[d]	6
Minot	ND	727676	MOT	1208440	468580	48.259	101.281	10.00[d]	6
Williston	ND	727670	ISN	1035942	453045	48.195	103.642	6.10[c]	6
Rapid City	SD	726620	RAP	1116674	-951	44.046	103.054	9.75[e]	7
Spokane	WA	727850	GEG	-2498	405056	47.621	117.528	10.00[c]	8
Casper	WY	725690	CPR	859003	-143037	42.898	106.473	10.00[c]	7
Lander	WY	725760	LND	662852	-159097	42.817	108.733	10.00[c]	7
Riverton	WY	725765	RIW	685693	-132898	43.064	108.459	10.00[d]	7
Sheridan	WY	726660	SHR	800522	60712	44.774	106.976	10.00[c]	7
Estevan	CAN[f]	718620	YEN	320189	1040790	49.217	-102.967	10.00[d]	6
Medicine Hat	CAN	718720	YXH	363110	610703	50.017	-110.717	10.00[d]	7

a. WBAN = Weather Bureau Army Navy.

b. U.S. latitudes and longitudes were obtained from following web site except for Coeur d'Alene and Salmon, ID: ftp://ftp.ncdc.noaa.gov/pub/data/inventories/ASOSLST.XLS. For those sites, the latitudes and longitudes were acquired from ftp://ftp.ncdc.noaa.gov/pub/data/inventories/COOP-ACT.TXT. The coordinates for the two Canadian stations were obtained from ftp://ftp.ncdc.noaa.gov/pub/data/inventories/ISH-HISTORY.TXT.

c. The anemometer heights were obtained from the following web site: http://www.wcc.nrcs.usda.gov/climate/windrose.html.

d. The anemometer heights for these stations could not be identified; therefore, the default National Weather Service anemometer height (10 m) was assigned.
e. These anemometer heights were obtained through the following web site: ftp://ftp.ncdc.noaa.gov/pub/data/inventories/.
f. CAN = Canada.

Upper air data will be obtained for one Canadian and seven U.S. sites. Table 3.4B lists the eight locations of the upper air data.

Table 3.4B: Upper Air Sites.

Station	State/ Country	WBAN[a] ID	Station Code	Grid Coordinates		Coordinates[b]		Time Zone
				X	Y	Latitude	Longitude	
Glasgow	MT	72768	GGW	813957	442859	48.200	106.620	7
Great Falls	MT	72776	TFX	458315	357277	47.450	111.380	7
Boise	ID	72681	BOI	57176	-52318	43.570	116.220	7
Bismarck	ND	72764	BIS	1266552	317294	46.770	100.750	6
Rapid City	SD	72662	UNR	1103707	223	44.070	103.210	7
Spokane	WA	72786	OTX	-9022	412770	47.680	117.630	8
Riverton	WY	72672	RIW	684047	-131807	43.060	108.470	7
Brooks	CAN[c]	71126	YBP	429973	711887	50.630	111.900	7

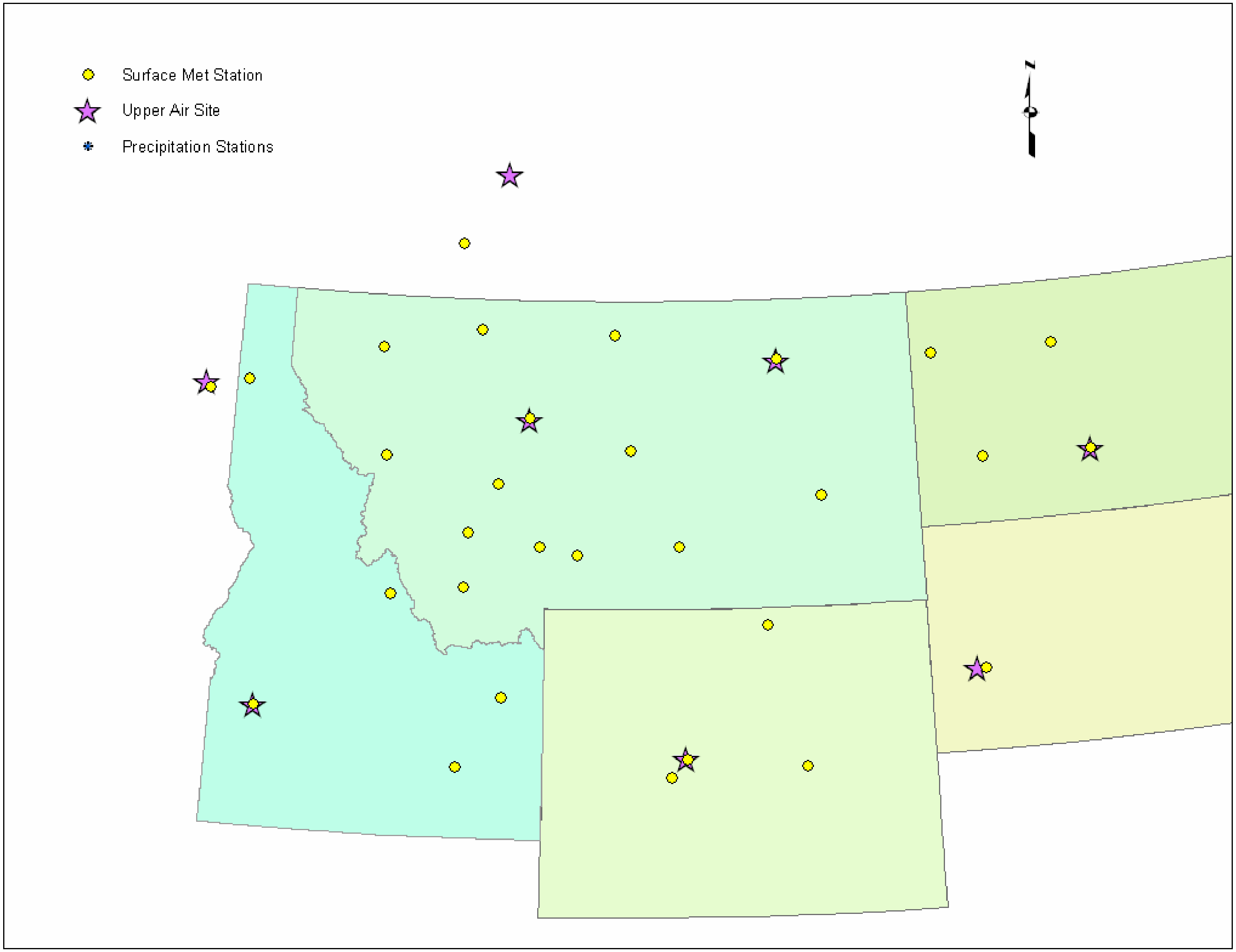
a. WBAN = Weather Bureau Army Navy.
b. Information was obtained from the following web site: http://raob.fsl.noaa.gov/intl/intl2000.wban.
c. CAN = Canada.

Precipitation data will be obtained from one hundred and forty-six (146) stations and are listed in Appendix B. Table 3.4C summarizes the total number and type of met stations, which are displayed in Figure 3.3.

Table 3.4C: Number And Type Of Met Stations.

Met Type	Number of Sites
Surface Air	31
Upper Air	8
Precipitation	146

Figure 3.3: Locations of Met Stations.



Any station, regardless of the type (surface, upper, or precipitation), located within the individual modeling subdomain for a BART-eligible/subject model run will be included in CALMET. Other stations will be selected depending upon their respective locations relative to the modeling subdomain.

3.5 CALMET CONTROL PARAMETERS

A listing of CALMET parameters that will be used in the Montana BART visibility demonstration is provided in Table 3.5. The IWAQM model defaults are also listed for comparison. The settings that differ from the IWAQM defaults are highlighted with the reasons for the differences noted. Some variables will change depending on the met year as noted by "will vary" or "Will Vary".

Table 3.5: Summary of CALMET Parameters.

CALMET Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
GEO.DAT	Name of Geophysical data file	GEO.DAT	GEO.DAT
SURF.DAT	Name of Surface data file	SURF.DAT	YYSURF.DAT[b] (will vary)
PRECIP.DAT	Name of Precipitation data file	PRECIP.DAT	YYPRECIP.DAT (will vary)
CALMET.LST	Name of CALMET list file	CALMET.LST	YYMET.LST (will vary)
CALMET.DAT	Name of CALMET output file	CALMET.DAT	YYMET.DAT (will vary)
MM4.DAT	MM4/MM5 data file	YEARMM4.DAT, YEARMM5.DAT	YYMM4.DAT, YYMM5.DAT (will vary)
PACOUT	MM4/MM5 output file	PACDAT	Will Vary
LCFILES	Keep file names in lower case {inconsequential}	T	F
NUSTA	Number of upper air data sites	≥ 1	Will vary depending on met year
UP1.DAT	Name of #1 Upper Air Station	UPN.DAT	YYUP1.DAT, YYUP2.DAT, etc.
UP2.DAT	Name of #2 Upper Air Station, etc.	UPN.DAT	
IBYR	Beginning year	Limited by MM4/MM5 Data	Will Vary
IBMO	Beginning month		Will Vary

CALMET Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
IBDY	Beginning day		Will Vary
IBHR	Beginning hour		Will Vary
IRLG	Number of hours to simulate		Will Vary
End of Year Specific Inputs			
SEADAT.DAT	Overwater files	SEAn.DAT	SEADAT.DAT
Other Files	Subgroup d: Diagnostic, Prognostic, etc. tests	Not Used	Not Used
IBTZ	Base time zone {inconsequential}	No Default	7
IRTYPE	Output file type to create (1 for CALPUFF)	1	1
LCALGRD	Compute Data Fields for CALGRID? (T = run CALGRID) {using CALPUFF photochemical model}	T	F
ITEST	Flag to stop run after setup phase (2 = run)	2	2
PMAP	Map Projection	LCC	LCC
FEAST	False Easting (if PMAP = TTM, LCC or LAZA) (km) {inconsequential}	0	60
FNORTH	False Northing (if PMAP = TTM, LCC or LAZA) (km)	0	0
IUTMZN	UTM Zone	User Defined	12
UTMHEM	Hemisphere for UTM Projection	N	N
RLAT0	Latitude (decimal degrees) of projection origin {inconsequential: domain size}	User Defined	44.25 N
RLON0	Longitude (decimal degrees) of projection origin {inconsequential: domain size}	User Defined	109.5 W
XLAT1	Latitude of 1st standard parallel {inconsequential: domain size}	User Defined	44 N
XLAT2	Latitude of 2nd standard parallel {inconsequential: domain size}	User Defined	49 N

CALMET Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
DATUM	Datum region for output coordinates	WGS-G	WGS-G
NX	Number of east-west grid cells	<= 190	To be determined, but <= 190
NY	Number of north-south grid cells	<= 135	To be determined, but <= 135
DGRIDKM	Grid spacing (km)	<= 12	6
XORIGKM	Southwest grid cell X coordinate	Use modeled coordinate system	0
YORIGKM	Southwest grid cell Y coordinate	Use modeled coordinate system	0
NZ	Number of vertical layers	>= 4	10
ZFACE	Vertical cell face heights (NZ + 1 values)	User Defined	0., 20., 40., 80., 160., 300., 600., 1000., 1500., 2200., 3000. (will vary with met year)
LSAVE	Save met. data fields in an unformatted file?	T	T
IFOMRO	Format of unformatted file (1 for CALPUFF)	1	1
LPRINT	Print met. fields?	F	F
IPRINF	Line printer output options.	Not Used	Not Used
NOOBS	No Observation Mode	0	0
NSSTA	Number of stations in SURF.DAT file	>= 1	Will vary with met year
NPSTA	Number of stations in PRECIP.DAT file	>= 1	Will vary with met year
ICLOUD	Is cloud data to be input as gridded fields? (0 = no) {As recommended by Kevin Golden, EPA Region VIII, 1/17/06}	0	0
IFORMS	Format of surface data (2 = formatted)	2	2
IFORMP	Format of precipitation data (2 = formatted)	2	2

CALMET Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
IFORMC	Format of cloud data (2 = formatted)	2	2
IWFCOD	Generate winds by diagnostic wind module? (1 = yes)	1	1
IFRADJ	Adjust winds using Froude number effects? (1 = yes)	1	1
IKINE	Adjust winds using kinematic effects? (0 = no)	0	0
IOBR	Use O'Brien procedure for vertical winds? (0 = no)	0	0
ISLOPE	Compute slope flows? (1 = yes)	1	1
IEXTRP	Extrapolate surface winds to upper layers (-4 = use similarity theory and ignore layer 1 of upper air station data)	-4	-4
ICALM	Extrapolate surface calms to upper layers? (0 = no)	0	0
BIAS	Surface/upper-air weighting factors (NZ values; IWAQM: NZ*0) other options were not available)	-1, (NZ-1) * 0	-1, (NZ-1) * 0
IPROG	Using prognostic or MM-FDDA data? (Use MM4/5 as initial guess wind)	MM4 or MM5	MM5 = 14
ISTEPPG	Timestep (hours) of the prognostic model input data	1	1
LVARY	Use varying radius to develop surface winds?	F	F
RMAX1	Maximum surface over land extrapolation radius (km)	No Default	30
RMAX2	Maximum aloft over land extrapolation radius (km)	No Default	100
RMAX3	Maximum over water extrapolation radius (km)	No Default	5
RMIN	Minimum extrapolation radius (km)	0.1	0.1
RMIN2	Distance (km) around an upper air site where vertical extrapolation is excluded {set to –1 if IEXTRP = $\pm$ 4}	4	-1
TERRAD	Radius of influence of terrain features (km) {evaluated by Kevin Golden, Region VIII, 1/17/06}	No Default	80

CALMET Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
R1	Relative weight at surface of Step 1 field and observation (km) {evaluated by Kevin Golden, Region VIII, 1/17/06}	No Default	30
R2	Relative weight aloft of Step 1 field and observation (km) {evaluated by Kevin Golden, Region VIII, 1/17/06}	No Default	50
RPROG	Relative weighting parameter of the prognostic wind field data (km)	0	0
DIVLIM	Maximum acceptable divergence	5.0 E-6	5.0 E-6
NITER	Max number of passes in divergence minimization	50	50
NSMTH	Number of passes in Smoothing (NZ values)	2, 4*(NZ-1)	2, 4*(NZ-1)
NINTR2	Max number of stations for interpolations (NZ values)	NZ *99	NZ *99
CRITFN	Critical Froude number	1.0	1.0
ALPHA	Empirical factor triggering kinematic effects	0.1	0.1
FEXTR2	Multiplicative scaling factor for extrapolation of surface observations to upper layers	NZ*0.0	NZ*0.0
NBAR	Number of barriers to interpolation of the wind fields (other variables if NBAR>0)	0	0
IDIOPT1	Compute temperature from observations (0 = true)	0	0
ISURFT	Surface station to use for surface temperature (between 1 and NSSTA)	No Default	Will vary with met year
IDIOPT2	Compute domain-average lapse rates? (0 = true)	0	0
IUPT	Station for lapse rates (between 1 and NUSTA)	User Defined	Will vary with met year
ZUPT	Depth of domain-average lapse rate (m)	200.	200.
IDIOPT3	Compute internally initial guess winds? (0 = true)	0	0
IUPWND	Upper air station for domain winds (-1 = $1/r^2$ interpolation of all stations)	-1	-1

CALMET Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
ZUPWND	Bottom, top of layer For 1st guess winds (m)	1, 1000	1, 1000
IDIOPT4	Read surface winds from SURF.DAT? (0 = true)	0	0
IDIOPT5	Read aloft winds from UPN.DAT? (0 = true)	0	0
LLBREZE	Use lake breeze module?	F	F
CONSTB	Neutral mixing height B constant	1.41	1.41
CONSTE	Convective mixing height E constant	0.15	0.15
CONSTN	Stable mixing height N constant	2400	2400
CONSTW	Over water mixing height W constant	0.16	0.16
FCORIOL	Absolute value of Coriolis parameter	1.0 E-4	1.0 E-4
IAVEXZI	Spatial averaging of mixing heights? (1 = true)	1	1
MNMDAV	Max averaging radius (number of grid cells)	1	1
HAFANG	Half-angle for looking upwind (degrees)	30	30
ILEVZI	Layer to use in upwind averaging (between 1 and NZ) {MDEQ professional judgement}	1	3
DPTMIN	Minimum capping potential temperature lapse rate	0.001	0.001
DZZI	Depth for computing capping lapse rate (m)	200	200
ZIMIN	Minimum over land mixing height (m)	50	50
ZIMAX	Maximum over land mixing height (m) {MDEQ professional judgement}	3000	2800
ZIMINW	Minimum over water mixing height (m)	50	50
ZIMAXW	Maximum over water mixing height (m) {MDEQ professional judgement}	3000	2800

CALMET Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
ITPROG	3D temperature from observations or from prognostic data?	0	0
IRAD	Form of temperature interpolation (1 = 1/r)	1	1
TRADKM	Radius of temperature interpolation (km)	500	500
NUMTS	Max number of stations in temperature interpolations	5	5
IAVET	Conduct spatial averaging of temperature? (1 = true)	1	1
TGDEFB	Default temperature gradient below the mixing height over water (K/m)	-0.0098	-0.0098
TGDEFA	Default temperature gradient above the mixing height over water (K/m)	-0.0045	-0.0045
JWAT1	Beginning (JWAT1) and ending (JWAT2) land use categories for temperature interpolation over water (bigger than largest land use to disable)	999	999
JWAT2		999	999
NFLAGP	Method for precipitation interpolation ($2 = 1/r^2$)	2	2
SIGMAP	Precipitation radius for interpolation (km)	100.0	100.0
CUTP	Minimum cut off precipitation rate (mm/hr)	0.01	0.01
SSn	NSSTA input records for surface stations	User Defined	Will vary with met year
USn	NUSTA input records for Upper-air stations	User Defined	Will vary with met year
PSn	NPSTA input records for precipitation stations	User Defined	Will vary with met year
JSUP	PG Stability class above mixed layer	5	5

a. IWAQM = Interagency Workgroup on Air Quality Modeling.
b. YY = Year of meteorology.

The CALMET output will contain the hourly gridded meteorological data. This data is fed into the dispersion model, CALPUFF.

4.0 CALPUFF INPUTS

The CALPUFF model requires the following data: source emissions, receptor locations/elevations (where the air pollutant concentrations will be calculated), meteorological, and geophysical. Background concentrations of ozone and ammonia will also be supplied. The meteorological and geophysical data will be first processed by CALMET, as discussed above, before entering CALPUFF model.

4.1 SOURCE EMISSIONS AND STACK DATA

For both BART applicability and degree of visibility improvement analyses, the guidelines specify that only primary emissions need to be considered.[2] For Montana BART-related modeling, the emissions of concern are sulfur dioxide (SO_2), nitrogen oxides (NO_X), and directly emitted particulate matter less than or equal to 10 microns (PM_{10}). The PM_{10} component includes both condensable and filterable particulates, if data are available.

As of February 2006, ten facilities have been identified with potential Montana BART-eligible sources (Figure 1B). The annual emissions used in the preliminary regional haze modeling by WRAP are provided in this protocol.

The WRAP used estimated the 2002 annual emissions of SO_2, NO_x, and PM_{10} for preliminary regional haze modeling. Emissions data from nine major point source were obtained from the EPA National Emission Inventory (NEI) and are listed in Table 4.1A; ASARCO was not included in the WRAP modeling. ASARCO has had "temporarily suspended" operations since the spring of 2001. The MDEQ did not include this facility's on WRAP's list of BART-eligible sources since some confusion arose due to Asarco's operational status. However, Asarco will remain on the MDEQ BART-eligible list, and in the event of reactivation of the East Helena facility, the MDEQ will seek compliance with BART.

Table 4.1A: Nine Facilities With Potential Montana BART-Eligible Sources And WRAP Estimated Annual Emissions.

BART-Eligible Facilities	WRAP[a] Annual Emissions Estimates			Calculated From WRAP Emissions Estimates		
	SO_2 (tpy)[b]	NO_x (tpy)	PM_{10} (tpy)	SO_2 (g/sec)[c]	NO_x (g/sec)	PM_{10} (g/sec)
Ash Grove Cement Company – Montana City	234	1,826	262	6.73	52.53	7.54
CHS Inc. (formerly Cenex Harvest States Cooperatives) – Laurel	2,064	974	91	59.38	28.02	2.62
Columbia Falls Aluminum LLC	584	7	224	16.80	0.20	6.44
Exxon Mobil Corporation – Billings Refinery	5,351	962	177	153.93	27.67	5.09

BART-Eligible Facilities	WRAP[a] Annual Emissions Estimates			Calculated From WRAP Emissions Estimates		
	SO_2 (tpy)[b]	NO_x (tpy)	PM_{10} (tpy)	SO_2 (g/sec)[c]	NO_x (g/sec)	PM_{10} (g/sec)
Holcim – Trident Plant	283	1,500	215	8.14	43.15	6.19
Montana Sulphur & Chemical Company	2,403	5	0	69.13	0.14	0.00
PPL Montana, LLC – Corette Plant	3,135	1,703	136	90.19	48.99	3.90
PPL Montana, LLC – Colstrip 1 & 2	16,735	32,631	498	481.40	938.71	14.33
Smurfit-Stone Container Enterprises, Inc.– Missoula	199	1,116	324	5.73	32.10	9.32

a. WRAP = Western Regional Air Partnership.
b. tpy = tons per year.
c. g/sec = grams per second.

The owner or operator of all potential Montana BART-eligible source(s) will be required to submit the primary emissions data to the MDEQ. These reported emissions data will represent the maximum steady-state 24-hour actual emissions rates (ignoring periods of startup, shutdown, and malfunction) from all BART-eligible source(s) at a given facility during a calendar year in the 2001 to 2003 period.

If the emissions during this period do not represent normal maximum production, the maximum 24-hour actual emission rates will be obtained from another recent year. All emissions data will be compared to the Montana annual emissions inventory reports for major stationary point sources during the same time period (2001 – 2003). For modeling, all emissions will be converted into grams per second (g/sec).

The MDEQ will assume that 99% of the PM_{10} emissions are particulate matter less than or equal to 2.5 microns ($PM_{2.5}$). The remaining 1% will be considered elemental carbon (EC). One source category, coal-fired power plants, will be treated differently.

Currently, the National Park Service (NPS) has recommended the following particulate matter (PM) speciation data for coal-fired power plants:

Fine Particulate Matter = 8%
Coarse Particulate Matter = 11%
Elemental Carbon = 1%
Secondary Organic Aerosols (Organic Carbon) = 16%
Sulfates = 64%

The MDEQ will use this speciation for all BART-eligible/subject coal-fired power plants. If better speciation data becomes available before modeling is completed, the MDEQ will apply that information if time, resources, and other relevant factors permit.

The owner or operator of all potential Montana BART-eligible source(s) will have an opportunity to submit source emissions and stack parameter data. Since the stack gas exit temperature and velocity may not be identical to produce the maximum 24-hour emissions of each pollutant, information should be provided for each individual pollutant.

The applicable stack parameters are listed in Table 4.1B. The owner or operator of all potential Montana BART-eligible source(s) will also need to specify the applicable units.

Table 4.1B: Example of Facility BART-Eligible Source Information.

Source	Pollutant	24-Hour Maximum Emission Rate		Emissions Year	Stack Coordinates			Stack Height[c]		Stack Inside Diameter		Gas Exit Temperature		Gas Exit Velocity	
		Value	Units[a]	2001-2003	X	Y	Datum[b]	Value	Units[d]	Value	Units[d]	Value	Units[e]	Value	Units[f]
Unit 1	NO_X														
	SO_2														
	PM_{10}														
Unit 2	NO_X														
	SO_2														
	PM_{10}														
Unit 3 (etc.): The previous 3 rows are repeated for each BART-eligible unit located at the same facility.															

a. Typical emission rate units are tons per day (tons/day) and pounds per day (lb/day).
b. Typical stack coordinates would be latitude/longitude or Universe Transverse Mercator (in both cases, datum must be specified: NAD27 or NAD83).
c. Stack height is above ground level.
d. Typical units of stack height and inside stack diameter are feet (ft) and meters (m).
e. Typical units of gas exit temperature are Fahrenheit (F), Centigrade (C), and Kelvin (K).
f. Typical units of gas exit velocity are feet per second (ft/sec) and meters per second (m/sec).

If the stack parameters are not provided, the MDEQ will be obtained this information from previous MDEQ modeling demonstrations, stack tests, or current Title V permit applications. The stack base elevations will be estimated through use of DEMS (Digital Elevation Models) derived from USGS 1:24,000 topographic map series. Building wake effects (downwash) will not be considered.

Each BART-eligible source (unit) will be assigned a unique 3-letter code. This system will simplify the identification of the CALPUFF runs for tracking purposes. Some BART-eligible sources may not be BART-subject, but the identification codes will not change for those sources that continue in the BART modeling process.

The BART guidelines discuss inclusion of volatile organic compounds (VOCs) and ammonia (NH_3) emissions in the modeling analysis, but the States were best qualified to make that decision. Due to lack of data, the MDEQ does not intend to include these emissions.

4.2 RECEPTOR LOCATIONS

All of the federally mandated Class I areas in Montana will be contained within the modeling domain. These Class I areas are listed in Table 4.2A with the corresponding IMPROVE site codes, acreage, responsible federal land manager, and the public law and date of the Class I designation.

Table 4.2A: Montana Federal Mandatory Class I Areas.

Class I Area	IMPROVE Code[a]	Acreage	Federal Land Manager	Public Law	Date
Anaconda-Pintler WA[b]	SULA1	157,803	USDA-FS[c]	88-577	September 3, 1964
Bob Marshall WA	MONT1	950,000	USDA-FS	88-577	September 3, 1964
Cabinet Mountains WA	CABI1	94,272	USDA-FS	88-577	September 3, 1964
Gates of the Mountains WA	GAMO1	28,562	USDA-FS	88-577	September 3, 1964
Glacier NP[d]	GLAC1	1,012,599	USDI-NPS[e]	61-171	May 11, 1910
Medicine Lake WA	YELL2	11,366	USDI-FWS[f]	94-557	October 19, 1976
Mission Mountains WA	MONT1	73,877	USDA-FS	93-632	January 3, 1975
Red Rock Lakes WA	YELL2	32,350	USDI-FWS	94-557	October 19, 1976
Scapegoat WA	MONT1	239,295	USDA-FS	92-395	August 20, 1972
Selway-Bitterroot WA[g]	SULA1	251,930	USDA-FS	88-577	September 3, 1964
U.L. Bend WA	ULBE1	20,890	USDI-FWS	94-557	October 19, 1976
Yellowstone NP[h]	YELL2	167,624	USDI-NPS	[i]	March 1, 1872

a. IMPROVE = Interagency Monitoring of Protected Visual Environments.
b. WA = Wilderness Area.
c. USDA-FS = U.S. Department of Agriculture - Forest Service.
d. NP = National Park.
e. USDI-NPS = U.S. Department of Interior - National Park Service.
f. USDI-FWS = U.S. Department of Interior – Fish and Wildlife Service.
g. Selway-Bitterroot Wilderness encompasses 1,240,700 acres; 988,770 acres are in Idaho and 251,930 acres are in Montana.
h. Yellowstone National Park total acreage is 2,219,737; 2,020,625 acres are in Wyoming, 167,624 acres are in Montana, and 31,488 acres are in Idaho.
i. 17 Stat. 32 (42nd Cong.), [44 FR 69124, Nov. 30, 1979; 45 FR 6103, Jan. 25, 1980].

Some of the IMPROVE site codes correspond to more than one Class I area. In these cases, even though the monitoring site may not lay in that Class I area, the composition of fine particles are representative of the shared airshed.

Four other Class I areas in neighboring states will be included in the analysis: Idaho (1), North Dakota (1), and Wyoming (2). The visibility in these areas may be affected by Montana BART-eligible/subject sources so they warranted inclusion. These Class I areas are listed in Table 4.2B with the corresponding IMPROVE site codes, acreage, responsible federal land manager, and the public law and date of Class I designation.

Table 4.2B: Four Neighboring Class I Areas Included In CALPUFF.

Class I Area	IMPROVE Code[a]	State	Acreage	Federal Land Manager	Public Law	Date
North Absaroka WA[b]	NOAB1	Wyoming	351,101	USDA-FS[c]	88-577	September 3, 1964
Selway-Bitterroot WA	SULA1	Idaho	988,770	USDA-FS	88-577	September 3, 1964
Theodore Roosevelt NP[d]	THRO1	North Dakota	69,675	USDI-NPS[e]	80-38	October 5, 1989
Yellowstone NP	YELL2	Wyoming	2,020,625	USDI-NPS	[f]	March 1, 1872

a. IMPROVE = Interagency Monitoring of Protected Visual Environments.
b. WA = Wilderness Area.
c. USDA-FS = U.S. Department of Agriculture - Forest Service.
d. NP = National Park.
e. USDI-NPS = U.S. Department of Interior - National Park Service.
f. 17 Stat. 32 (42nd Cong.), [44 FR 69124, Nov. 30, 1979; 45 FR 6103, Jan. 25, 1980].

All significant Class I areas are displayed in Figure 1.0B. The National Park Service (NPS) has provided the receptor locations with elevations for all sixteen Class I areas. Each area was also assigned a unique code, which will be retained by the MDEQ for tracking purposes. The assigned NPS codes and number of receptors for the sixteen Class I area that will be evaluated are listed in Table 4.2C; the locations of all relevant receptors are shown in Figure 4.2. Note that the receptor maps are not to scale.

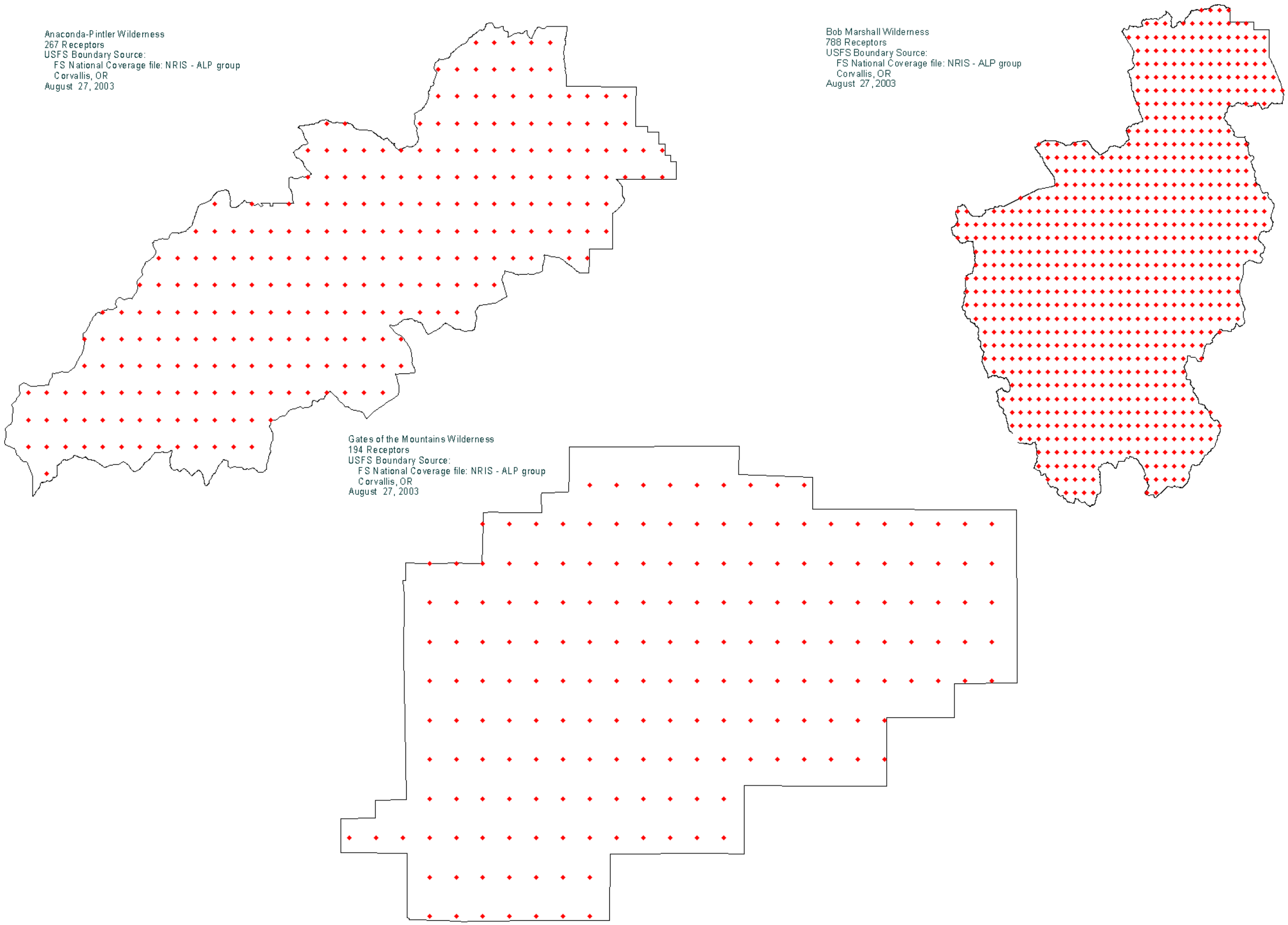
Table 4.2C: NPS Code and Number of Receptors Of Significant 16 Class I Areas.

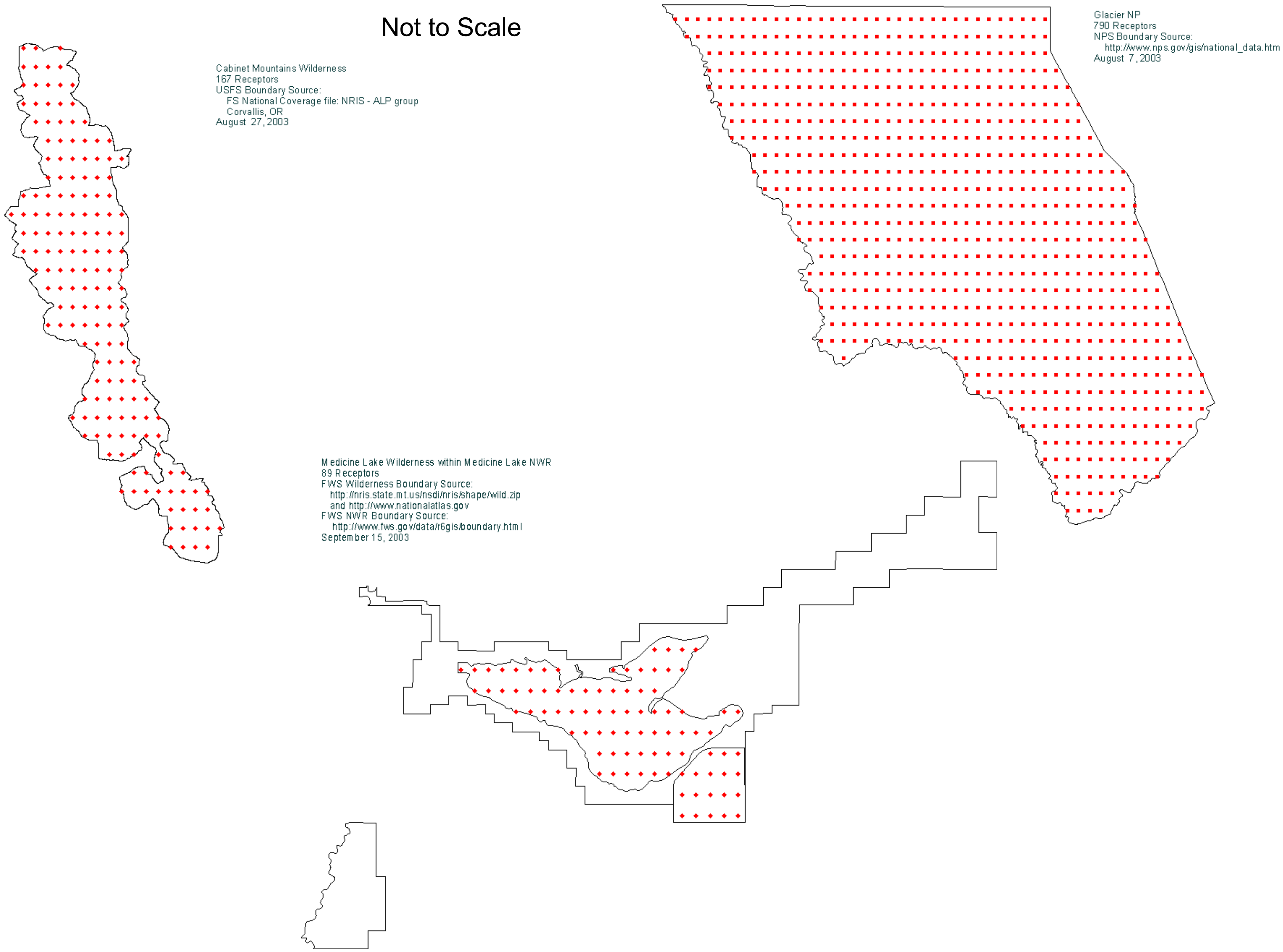
Class I Area	NPS[a] Code	Number of Receptors	Class I Area	NPS Code	Number of Receptors
Anaconda-Pintler WA	anac2	267	Scapegoat WA	scap2	423
Bob Marshall WA	boma3	788	Selway-Bitterroot WA	selw4	575[b]
Cabinet Mountains WA	camo2	167	U.L. Bend WA	ulbewild	134
Gates of the Mountains WA	gamo	194	Yellowstone NP	yell4	915[c]
Glacier NP	glac3	790	North Absaroka WA - WY	noab2	567
Medicine Lake WA	mediwild	89	Selway-Bitterroot WA – ID	selw4	575[b]
Mission Mountains WA	mimo2	130	Theodore Roosevelt NP - ND	thro	489
Red Rock Lakes WA	redrwild	222	Yellowstone NP – WY	yell4	915[c]

a. NPS = National Park Service.
b. Selway-Bitterroot Wilderness Area receptors are in both Montana and Idaho.

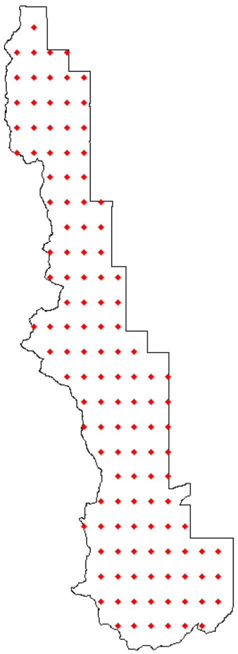
[c] Yellowstone National Park receptors are in Montana, Idaho, and Wyoming.

Figure 4.2: Receptor Locations of Significant Class I Areas (Not to Scale).



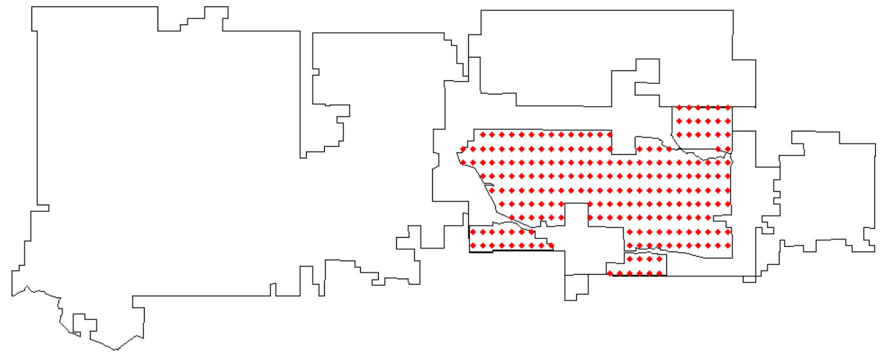

Not to Scale
Cabinet Mountains Wilderness
167 Receptors
USFS Boundary Source:
FS National Coverage file: NRIS - ALP group
Corvallis, OR
August 27, 2003
Glacier NP
790 Receptors
NPS Boundary Source:
http://www.nps.gov/gis/national_data.htm
August 7, 2003
Medicine Lake Wilderness within Medicine Lake NWR
89 Receptors
FWS Wilderness Boundary Source:
http://nris.state.mt.us/nsdi/nris/shape/wild.zip
and http://www.nationalatlas.gov
FWS NWR Boundary Source:
http://www.fws.gov/data/r6gis/boundary.html
September 15, 2003

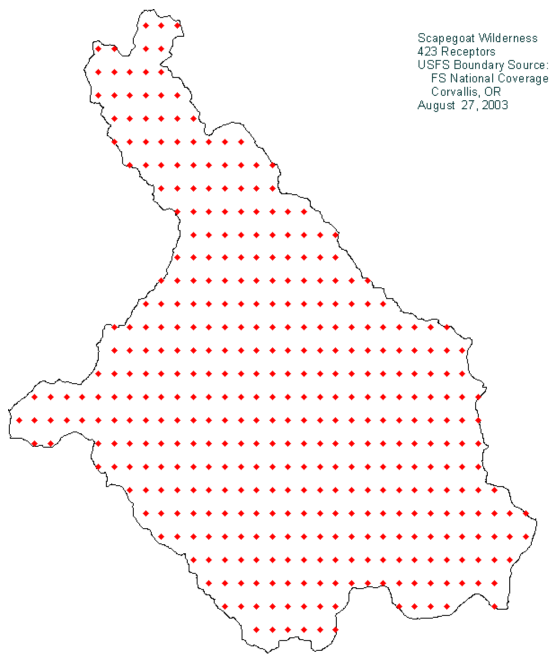
Not to Scale



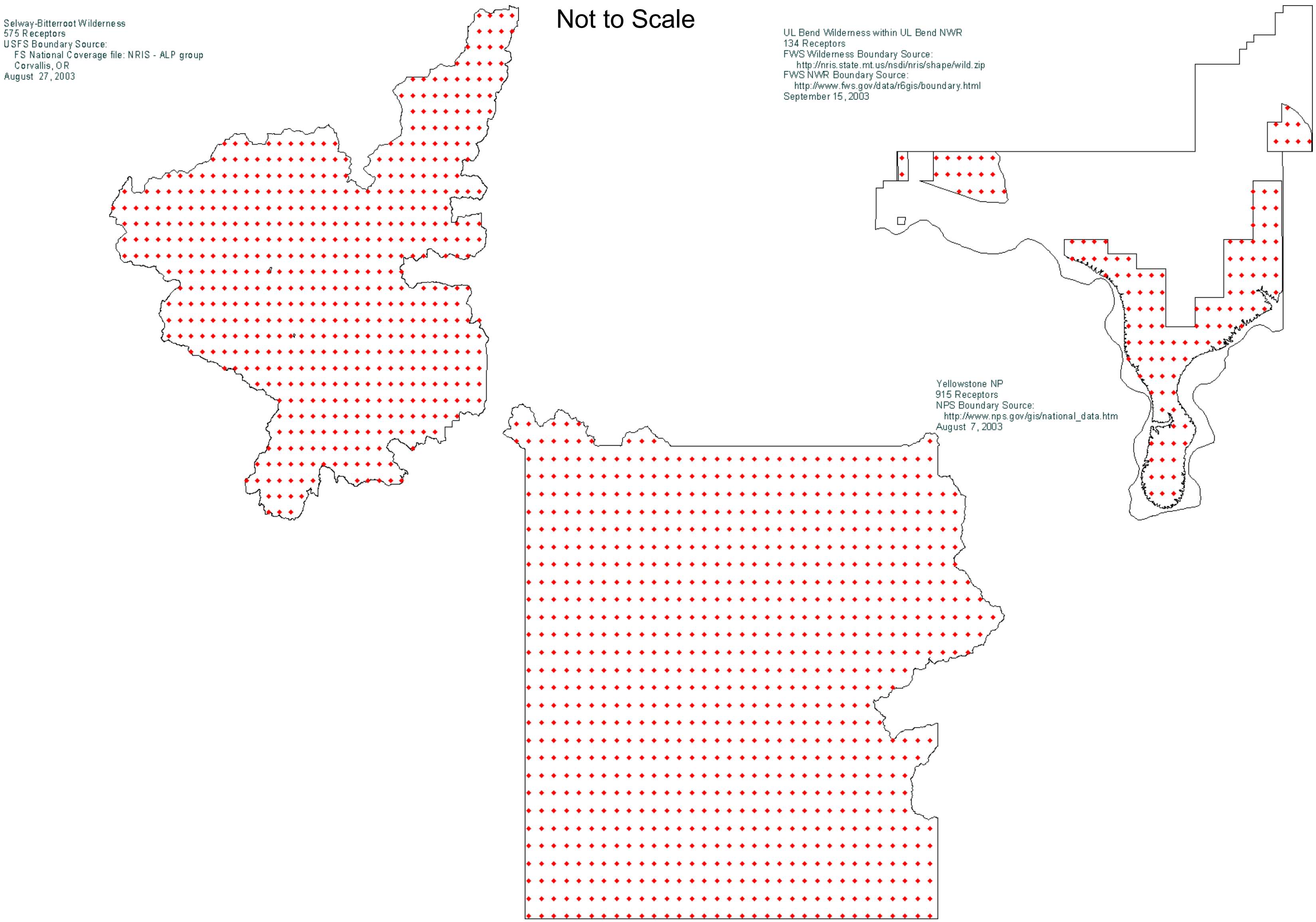
Mission Mountains Wilderness
130 Receptors
USFS Boundary Source:
FS National Coverage file: NRIS - ALP group
Corvallis, OR
August 27, 2003

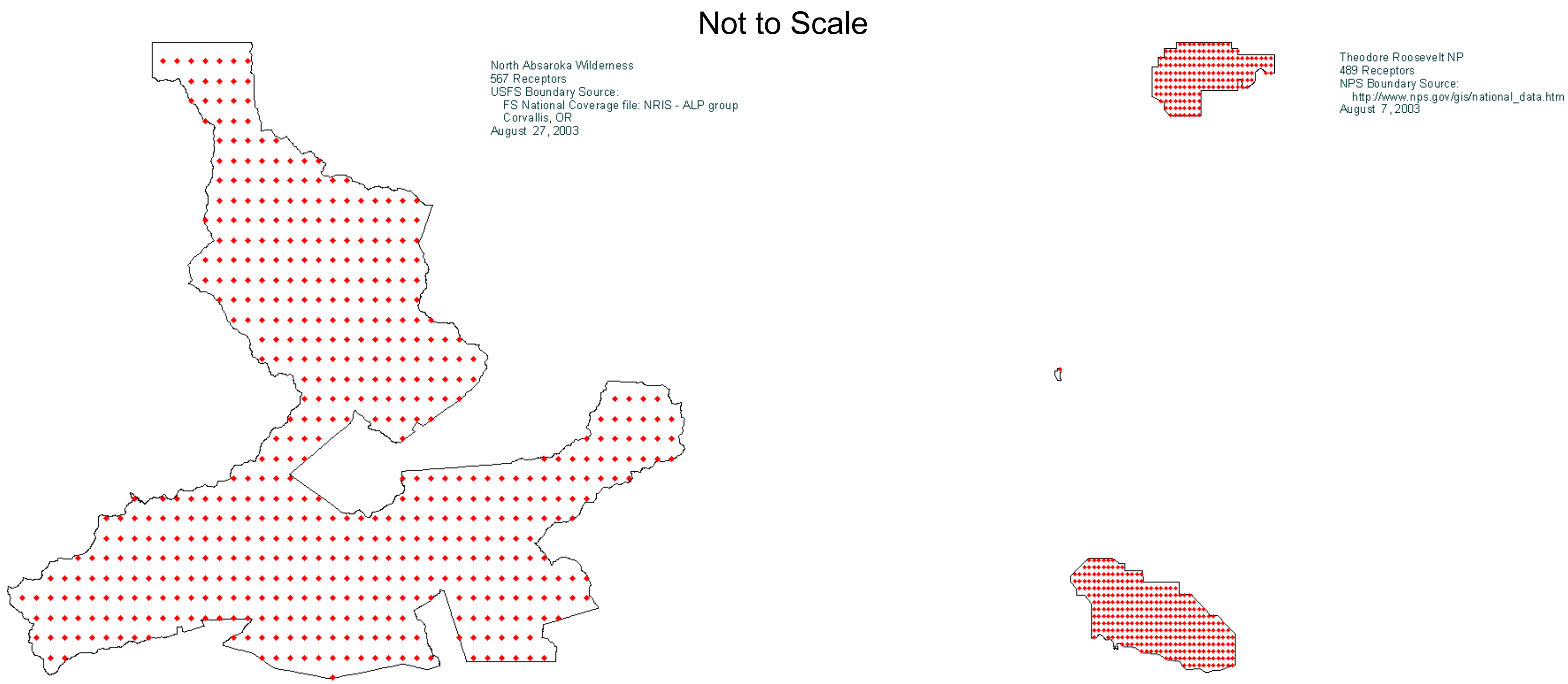
Red Rock Lakes Wilderness within Red Rock Lakes NWR
222 Receptors
FWS Wilderness Boundary Source:
http://nris.state.mt.us/nsdi/nris/shape/wild.zip
FWS NWR Boundary Source:
http://www.fws.gov/data/r6gis/boundary.html
September 15, 2003





Scapegoat Wilderness
423 Receptors
USFS Boundary Source:
FS National Coverage file: NRIS - ALP group
Corvallis, OR
August 27, 2003


Not to Scale
Selway-Bitterroot Wilderness
575 Receptors
USFS Boundary Source:
FS National Coverage file: NRIS - ALP group
Corvallis, OR
August 27, 2003
UL Bend Wilderness within UL Bend NWR
134 Receptors
FWS Wilderness Boundary Source:
http://nris.state.mt.us/nsdi/nris/shape/wild.zip
FWS NWR Boundary Source:
http://www.fws.gov/data/r6gis/boundary.html
September 15, 2003
Yellowstone NP
915 Receptors
NPS Boundary Source:
http://www.nps.gov/gis/national_data.htm
August 7, 2003



The original files were in North America Datum 1983 (NAD83) UTM (Universe Transverse Mercator) coordinates. A Corps of Engineers coordinate conversion software called Corpscon (Version 6.0) will be used to convert the coordinates to the Montana State Plane coordinates. The software was downloaded from the following web site: (http://crunch.tec.army.mil/software/corpscon/corpscon.html).

4.3 BACKGROUND CONCENTRATIONS OF OZONE AND AMMONIA

CALPUFF allows background concentrations of ozone and ammonia to vary in both space and time. The MDEQ will use the available albeit limited data to utilize the chemistry modules in CALPUFF.

4.3.1 BACKGROUND OZONE

Background ozone concentrations are important for the photochemical conversion of sulfur dioxide (SO_2) and nitrous oxides (NO_x) to sulfates (SO_4) and nitrates (NO_3), respectively. CALPUFF can use either a single background value representative of an area or hourly ozone data from one or more ozone monitoring stations (the preferred method).

Hourly ozone data is collected at two Montana federal mandatory Class I areas: Glacier and Yellowstone National Parks. These data are available on the CASTNET web site (http://www.epa.gov/castnet/ozone.html). CASTNET is the EPA Clean Air Status and Trends Network, and is the primary source for national data on dry acid deposition and rural, ground-level ozone. Three years of data (2001 – 2003) will be used in CALPUFF. For comparison, the IWAQM Phase 2 report recommends using an 80 parts per billion ozone default for missing data.

4.3.2 BACKGROUND AMMONIA

Ambient concentrations of nitrate (NO_3) are limited by the availability of ammonia, which is preferentially scavenged by sulfates (SO_4). Due to this preferential reaction between ammonia and sulfates, a lower ammonia concentration would tend to decrease particle nitrate concentrations prior to affecting particle sulfate concentrations.

In CALPUFF, a continuous emissions plume is represented by a series of puffs. The model allows the full amount of the background ammonia concentrations to be available to each emissions puff to form nitrate, which tends to overestimate nitrate formation. To compensate, an ammonia-limiting method will be used in the post-processing phase of CALPUFF model system.

Ammonia has never been measured in Montana. However, the North Dakota Department of Health collects hourly ammonia data at one site near Beulah. The MDEQ believes this data is representative of Montana background ammonia concentrations and the EPA concurs (John Coefield, MDEQ, telephone conversation with Kevin Golden, EPA Region VIII, January 25, 2006). Monthly values were calculated from hourly ammonia data collected from 2001 to 2002, which are displayed in Table 4.3.2. These background ammonia concentrations will be used in the CALPUFF modeling.

Table 4.3.2: Monthly Background Ammonia Concentrations.

Month	Ammonia Concentration (ppb)[a]
January	1.22
February	1.23
March	1.60
April	1.94
May	2.29
June	1.63
July	1.65
August	1.69
September	0.98
October	1.04
November	1.37
December	1.06

[a.] ppb = parts per billion.

For comparison, the IWAQM Phase 2 report default monthly ammonia background concentration is 10.0 ppb (parts per billion).

4.4 CALPUFF MODEL CONTROL PARAMETERS

A summary of the CALPUFF model control parameters that MDEQ will use are listed in Table 4.4. The IWAQM model defaults are also listed for comparison. The settings that differ from the IWAQM defaults are highlighted with the reasons for the differences noted. Some variables will change depending on the meteorological year as noted by "will vary".

Table 4.4: Summary of CALPUFF Inputs.

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
METDAT	CALMET input data filename	CALMET.DAT	YYMET.DAT[b] (will vary)
PUFLST	Filename for general output from CALPUFF	CALPUFF.LST	YYXXX.LST[c] (will vary)
CONDAT	Filename for output concentration data	CONC.DAT	YYXXXCONC.DAT (will vary)
DFDAT	Filename for output dry deposition fluxes	DFLX.DAT	YYXXXDFLX.DAT (will vary)
WFDAT	Filename for output wet deposition fluxes	WFLX.DAT	YYXXXWFLX.DAT (will vary)

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
VISDAT	Filename for output relative humidities	VISB.DAT	YYXXXRH.DAT (will vary)
OZDAT	Name of ozone data files (GNP = Glacier NP, YNP = Yellowstone NP)	OZDAT.DAT	YYGNPOZ.DAT, YYYNPOZ.DAT
LCFILES	File names converted to lower case if T, upper case if F {inconsequential}	T	F
NMETDAT	Number of CALMET.DAT files for run	1	1
METRUN	Run all periods (1) or period defined (0)?	0	0
XBTZ	Base time zone: PST = 8, MST = 7, CST = 6, EST = 5	7	7
First Met Data Inputs; Repeated for Each Met Year			
IBYR	Beginning year	User Defined	Will vary with met year
IBMO	Beginning month	Limited by MM4/MM5 Data	Will vary with met year
IBDY	Beginning day		Will vary with met year
IBHR	Beginning hour		Will vary with met year
IRLG	Length of run (hours)		Will vary with met year
End of Year-Specific Inputs			
NSPEC	Number of species modeled (for MESOPUFF II chemistry)	5	Will vary with source
NSE	Number of species emitted	3	Will vary with source
ITEST	Flag to stop run after SETUP phase (1 = stop, 2 = continue)	2	2
MRESTART	Restart options allows splitting runs into smaller segments options (0=no restart)	0	0
NRESPD	Number of periods in Restart output cycle	0	0
METFM	Format of input meteorology (1 = CALMET)	1	1

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
AVET	Averaging time lateral dispersion parameters (minutes)	60	60
PGTIME	PG Averaging Time	60	60
MGAUSS	Near-field vertical distribution (1 = Gaussian)	1	1
MCTADJ	Terrain adjustments to plume path (3 = partial plume path adjustment)	3	3
MCTSG	Subgrid-scale complex terrain (0 = not modeled, 1 = modeled)	0	0
MSLUG	Near-field puffs modeled as elongated (0 = no, 1 = slugs modeled)	0	0
MTRANS	Model transitional plume rise? (1 = yes)	1	1
MTIP	Treat stack tip downwash? (1 = yes)	1	1
MBDW	Method used to simulate building downwash (1 = ISC, 2 = PRIME) {building downwash not considered}	2	Not Used
MSHEAR	Vertical wind shear modeled above stack top (0 = no, 1 = yes)	0	0
MSPLIT	Allow puffs to split? (0 = no, 1 = yes) {As recommended by EPA Region VIII, Kevin Golden, 2/23/06}	0	1
MCHEM	Chemical mechanism flag (1 = MESOPUFF II chemistry)	1	1
MAQCHEM	Aqueous phase transformation (0 = not modeled, 1 = aqueous phase reactions)	0	0
MWET	Model wet deposition? (1 = yes)	1	1
MDRY	Model dry deposition? (1 = yes)	1	1
MDISP	Method for dispersion coefficients (3 = PG & MP)	3	3
MTURBVW	Turbulence characterization (only if MDISP = 1 or 5) {see previous variable}	3	Not Used

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
MDISP2	Backup coefficients (only if MDISP = 1 or 5) {see previous variable}	3	Not Used
MROUGH	Adjust PG for surface roughness? (0 = no)	0	0
MPARTL	Model partial plume penetration (1=yes)	1	1
MTINV	Strength of temperature inversion (0 = compute from data)	0	0
MPDF	Use PDF for convective dispersion? (0 = no)	0	0
MSGTIBL	Use TIBL model? (allows treatment of subgrid scale coastal areas, 0 = no)	0	0
MBCON	Boundary condition concentration modeled? (0 = no)	0	0
MFOG	Configure for FOG Model output? (0 = no)	0	0
MREG	Regulatory default checks? (1 = yes)	1	1
CSPEC	Names of species modeled (NSE names)	MESOPUFF II must be SO_2, SO_4, NOx, HNO_3, NO_3	SO_2, SO_4, NOx, HNO_3, NO_3, others may be included depending on the source

EXAMPLE:

SPECIES NAME	MODELED (0 = NO, 1 = YES)	EMITTED (0= NO, 1 = YES)	DRY DEPOSITED (0= NO, 1 = COMPUTED –GAS 2 = COMPUTED – PARTICLE 3 = USER-SPECIFIED)	OUTPUT GROUP NUMBER (0 = NONE 1 = 1st CGRUP, 2 = 2nd CGRUP, 3 = etc.)
SO_2 =	1,	1,	1,	0!
SO_4 =	1,	0,	2,	0!
NO_X =	1,	1,	1,	0!
HNO_3 =	1,	0,	1,	0!
NO_3 =	1,	0,	2,	0!
PMF =	1,	0,	2,	0!
PMC =	1,	1,	2,	0!
EC =	1,	0,	2,	0!

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
CGRUP	Grouping of species, if any	User Defined	Not Used
PMAP	Map Projection (Use LCC for source-receptor distance >100 km)	LCC	LCC

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
FEAST	False Easting (if PMAP = TTM, LCC or LAZA) (km) {inconsequential}	0	60
FNORTH	False Northing (if PMAP = TTM, LCC or LAZA) (km)	0	0
IUTMZN	UTM Zone	User Defined	12
UTMHEM	Hemisphere for UTM Projection	User Defined	N
RLAT0	Latitude (decimal degrees) of projection origin	User Defined	44.25 N
RLON0	Longitude (decimal degrees) of projection origin	User Defined	109.5 W
XLAT1	Latitude of 1st standard parallel	User Defined	44 N
XLAT2	Latitude of 2nd standard parallel	User Defined	49 N
DATUM	Datum-region for output coordinates	WGS-G	WGS-G
NX	Number of east-west grid cells	<= 190	To be determined, but <= 190
NY	Number of north-south grid cells	<= 135	To be determined, but <= 135
NZ	Number of vertical layers	>= 4	11
ZFACE	Vertical cell face heights (NZ + 1 values)	User Defined	Will vary with met year
DGRIDKM	Grid spacing (km)	<= 12	6
XORIGKM	Southwest grid cell X coordinate	Use modeled coordinate system	Varies with subdomain
YORIGKM	Southwest grid cell Y coordinate		Varies with subdomain
IBCOMP	Southwest X-index of computational domain	1 <= IBCOMP <= NX	1
JBCOMP	Southwest Y-index of computational domain	1 <= JBCOMP <= NY	1
IECOMP	Northeast X-index of computational domain	1 <= IBCOMP <= NX	To be determined, but <= 190

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
JECOMP	Northeast Y-index of computational domain	1 <= JBCOMP <= NY	To be determined, but <= 135
LSAMP	Use gridded receptors? (T = yes) {NPS receptors are discrete}	T	F
IBSAMP	Southwest X-index of receptor grid	IBCOMP <= IBSAMP <= IECOMP	Not Used
JBSAMP	Southwest Y-index of receptor grid	JBCOMP <= JBSAMP <= JECOMP	Not Used
IESAMP	Northeast X-index of receptor grid	IBCOMP <= IESAMP <= IECOMP	Not Used
JESAMP	Northeast Y-index of receptor grid	JBCOMP <= JESAMP <= JECOMP	Not Used
MESHDN	Gridded receptor spacing = DGRIDKM/MESHDN	1	Not Used
ICON	Output concentrations? (1 = yes)	1	1
IDRY	Output dry deposition flux? (1 = yes)	1	1
IWET	Output wet deposition flux? (1= yes)	1	1
IVIS	Output RH for visibility calculations? (1 = yes)	1	1
LCOMPRS	Use compression option in output? (T = yes)	T	T
IMFLX	Mass Flux Across Boundary> (0 = no)	0	0
IMBAL	Mass balance for each species? (0 = no)	0	0
ICPRT	Print concentrations? (0 = no) {QA/QC check}[d]	0	1
IDPRT	Print dry deposition fluxes? (0 = no) {QA/QC check}	0	1
IWPRT	Print wet deposition fluxes? (0 = no) {QA/QC check}	0	1
ICFRQ	Concentration print interval (1 = hourly) {interested in 24-hr values}	1	24
IDFRQ	Dry deposition flux print interval (1 = hourly) {interested in 24- hr values}	1	24

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
IWFRQ	Wet deposition flux print interval (1 = hourly) {interested in 24-hr values}	1	24
IPRTU	Print output units (3 = μg/m^3, μg/m^3/s)	3	3
IMESG	Status messages to screen (2 = yes, date, # of puffs)	2	2
SPECIES	Species List for Output	All species saved on disk	All species printed and saved on disk
LDEBUG	Turn on debug tracking? (F = no)	F	F
IPFDEB	First puff to track	1	1
NPFDEB	Number of puffs to track	1	1
NN1	Met. period (hour) to start debug output	1	1
NN2	Met. period (hour) to end debug output	10	10
NHILL	Number of subgrid terrain (hill) features	0	0
NCTREC	Number of special complex terrain receptors	0	0
MHILL	Terrain and CTSG Receptor data for CTSG hills input in CTDM format ? (1 = Hill and rec. data read from files, 2 = hill data created) {not used since NHILL = 0}	1	0
XHILL2M	Factor to convert horizontal dimensions to meters {not used since NHILL = 0}	1	0
ZHILL2M	Factor to convert vertical dimensions to meters {not used since NHILL = 0}	1	0
XCTDMKM	X-origin of CTDM system relative to CALPUFF coordinate system (km)	0.0E00	0.0E00
YCTDMKM	Y-origin of CTDM system relative to CALPUFF coordinate system (km)	0.0E00	0.0E00
Chemical Parameters Of Gaseous Deposition Species			

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
	DIFFUSIVITY (cm^2/s)	SO_2 = 0.1509 NOx = 0.1656 HNO_3 = 0.1628	SO_2 = 0.1509 NOx = 0.1656 HNO_3 = 0.1628
	ALPHA STAR	SO_2 = 1000. NOx = 1. HNO_3 = 1.	SO_2 = 1000. NOx = 1. HNO_3 = 1.
	REACTIVITY	SO_2 = 8. NOx = 8. HNO_3 = 18.	SO_2 = 8. NOx = 8. HNO_3 = 18.
	MESOPHYLL RESISTANCE (s/cm)	SO_2 = 0. NOx = 5. HNO_3 = 0.	SO_2 = 0. NOx = 5. HNO_3 = 0.
	HENRY'S LAW COEFFICIENT	SO_2 = 0.04 NOx = 3.5 HNO_3 = 0.00000008	SO_2 = 0.04 NOx = 3.5 HNO_3 = 0.00000008
Size Parameters For Dry Deposition Of Particles			
	GEOMETRIC MASS MEAN DIAMETER (microns)	SO_4 = 0.48 NO_3 = 0.48 PMF = 0.48 PMC = 0.48 EC = 0.48	SO_4 = 0.48 NO_3 = 0.48 PMF = 0.48 PMC = 0.48 EC = 0.48 OC = 0.48 (will vary with source)
	GEOMETRIC STANDARD DEVIATION (microns)	SO_4 = 2. NO_3 = 2. PMF = 2. PMC = 2. EC = 2.	SO_4 = 2. NO_3 = 2. PMF = 2. PMC = 2. EC = 2. OC = 2. (will vary with source)
RCUTR	Reference cuticle resistance (s/cm)	30.	30.
RGR	Reference ground resistance (s/cm)	10.	10.
REACTR	Reference reactivity	8	8
NINT	Number of particle-size intervals	9	9
IVEG	Vegetative state (1 = active and unstressed)	1	1
Wet Deposition Parameters			
	Scavenging Coefficient, Liquid Precipitation $(sec)^{-1}$	SO_2 = 3.0E-05 SO_4 = 1.0E-04 HNO_3 = 6.0E-05 NO_3 = 1.0E-04 PMF = 1.0E-04 PMC = 1.0E-04 EC = 1.0E-04	SO_2 = 3.0E-05 SO_4 = 1.0E-04 HNO_3 = 6.0E-05 NO_3 = 1.0E-04 PMF = 1.0E-04 PMC = 1.0E-04 EC = 1.0E-04 OC = 1.0E-04

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
			(will vary with source)
	Scavenging Coefficient, Frozen Precipitation (sec^{-1})	SO_2 = 0.0E-00 SO_4 = 3.0E-05 HNO_3 = 0.0E-00 NO_3 = 3.0E-05 PMF = 3.0E-05 PMC = 3.0E-05 EC = 3.0E-05	SO_2 = 0.0E-00 SO_4 = 3.0E-05 HNO_3 = 0.0E-00 NO_3 = 3.0E-05 PMF = 3.0E-05 PMC = 3.0E-05 EC = 3.0E-05 OC = 3.0E-05 (will vary with source)
MOZ	Ozone background (1 = read from ozone.dat)	1	1
BCKO3	Ozone default (ppb) for missing data	12 * 80	Will use monthly ozone data from Yellowstone and Glacier National Parks
BCKNH3	Ammonia background (ppb) {North Dakota data}	12 * 10	1.22, 1.23, 1.60, 1.94, 2.29, 1.63, 1.65, 1.69, 0.98, 1.04, 1.37, 1.06
RNITE1	Nighttime SO_2 loss rate (%/hr)	0.2	0.2
RNITE2	Nighttime NOx loss rate (%/hr)	2.0	2.0
RNITE3	Nighttime HNO_3 loss rate (%/hr)	2.0	2.0
MH202	H2O2 data input option (MAQCHEM = 1; 0 = monthly background, 1 = read hourly conc. file) {using MAQCHEM = 0}	0	Not Used
BCKH2O2	Monthly H2O2 concentrations (ppb)	12 * 1.0	12 * 1.0
BCKPMF	Fine particulate concentration ($\mu g/m^3$) (used if MCHEM = 4 with VOC emissions) {using MAQCHEM = 1; no VOC emissions}	12 * 1.00	Not Used
OFRAC	Organic fraction of fine particulate (Used with VOC emissions) {no VOC emissions}	2*0.15, 9*0.20, 1*0.15	Not Used
VCNX	VOC / NOX ratio (after reaction; Used with VOC emissions) {no VOC emissions}	12 * 50.00	Not Used
SYTDEP	Horizontal size (m) to switch to time dependence	550.	550.
MHFTSZ	Use Heffter for vertical dispersion (0 = no)	0	0.

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
JSUP	PG Stability class above mixed layer	5	5
CONK1	Vertical stable dispersion constant (Eq. 2.7-3)	0.01	0.01
CONK2	Vertical neutral dispersion constant (Eq. 2.7-4)	0.1	0.1
TBD	Factor for determining Transition-point from Schulman-Scire to Huber-Snyder Building Downwash scheme	0.5	0.5
IURB1	Beginning urban land use type	10	10
IURB2	Ending urban land use type	19	19
XMXLEN	Maximum slug length in units of DGRIDKM	1	1
XSAMLEN	Maximum puff travel distance per sampling step (units of DGRIDKM)	1	1
MXNEW	Maximum number of puffs per hour	99	99
MXSAM	Maximum sampling steps per hour	99	99
NCOUNT	Number of iterations used when computing the transport wind for a sampling step that includes gradual rise (for CALMET and PROFILE winds)	2	2
SYMIN	Minimum lateral dispersion of new puff/slug (m)	1.0	1.0
SZMIN	Minimum vertical dispersion of new puff/slug (m)	1.0	1.0
SVMIN	Default minimum turbulence velocities for stability classed A-F (m/s)	6 * 0.50	6 * 0.50
SWMIN		0.20, 0.12, 0.08, 0.06, 0.03, 0.016	0.20, 0.12, 0.08, 0.06, 0.03, 0.016
CDIV(2)	Divergence criterion for dw/dz (s^{-1})	0.0, 0.0	0.0, 0.0
WSCALM	Minimum non-calm wind speed (m/s)	0.5	0.5
XMAXZI	Maximum mixing height (m)	3000	2800

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
XMINZI	Minimum mixing height (m)	50	50
WSCAT	Upper bounds of first 5 wind speed classes (m/s)	1.54, 3.09, 5.14, 8.23, 10.8	1.54, 3.09, 5.14, 8.23, 10.8
PLX0	Wind speed power-law exponents (rural)	0.07, 0.07, 0.10, 0.15, 0.35, 0.55	0.07, 0.07, 0.10, 0.15, 0.35, 0.55
PTG0	Potential temperature gradients PG E and F (deg K/m)	0.020, 0.035	0.020, 0.035
PPC	Plume path coefficients for stability classes A-F (only if MCTADJ=3)	0.5, 0.5, 0.5, 0.5, 0.35, 0.35	0.5, 0.5, 0.5, 0.5, 0.35, 0.35
SL2PF	Maximum Sy/puff length	10	10
NSPLIT	Number of puffs when puffs split {As recommended by EPA Region VIII, Kevin Golden, 2/23/06}	3	2
IRESPLIT	Hours when puff are eligible to split	0, except hr 17 = 1	0, except hr 17 = 1
ZISPLIT	Split allowed last hour's mixing height exceeds minimum value (m)	100	100
ROLDMAX	Previous Max mixing height/current mixing height ratio, must be less than this value to allow puff split	0.25	0.25
NSPLITH	Number of puffs that result every time a puff is split	5	5
SYSPLITH	Min. Sy of puff before it splits	1	1
SHSPLITH	Minimum puff elongation rate (SYSPLITH/hr) due to wind shear, before it may be split	2.0	2.0
CNSPLITH	Minimum concentration (g/m^3) of each species in puff before it may be split (Array of NSPEC values or a single value for all species)	1.0E-07	1.0E-07
EPSSLUG	Fractional convergence criterion for numerical SLUG sampling integration	1.0E-04	1.0E-04
EPSAREA	Fractional convergence criterion for numerical AREA source integration	1.0E-06	1.0E-06
DSRISE	Trajectory step-length (m) used for numerical rise integration	1	1

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
NPT1	Number of point sources	No Default	To be determined
IPTU	Units of emission rates (1 = g/s)	1	1
NSPT1	Number of point source-species combinations	0	0
NPT2	Number of point sources with fully variable emission rates	0	0
IVARY	IVARY determines the type of variation, and is source-specific: (Default: 0 = constant)	0	0
NREC	Number of Non-gridded receptors	>=1	Will vary with subdomain

a. IWQMA = Interagency Workgroup on Air Quality Modeling.
b. YY = Year of meteorology.
c. XXX = unique MDEQ identification code for each individual BART-eligible/subject source.
d. QA/QC = quality assurance/quality control check.

The CALPUFF outputs will be hourly concentrations of the individual aerosol specie at each receptor for each met year. These results will be post-processed by two programs: POSTUTIL and CALPOST. The POSTUTIL will be used to implement the ammonia-limiting method before CALPOST calculates the 24-hour visibilities.

5.0 POSTUTIL INPUTS

According to Escoffier-Czaja and Scire:[6]

> "In CALPUFF, a continuous plume is simulated as a series of puffs, or discrete plume elements. The total concentration at any point in the model is the sum of the contribution of all nearby puffs from each source. Because CALPUFF allows the full amount of the specified background concentration of ammonia to be available to each puff for forming nitrate, the same ammonia may be used multiple times in forming nitrate, resulting in an overestimate of nitrate formation. In POSTUTIL, ammonia availability is computed based on receptor concentrations of total sulfate and total nitrate (HNO3 + NO3), not on a puff-by puff basis."

6. Escoffier-Czaja, Christelle and J. Scire. 2002. The Effects of Ammonia Limitation on Nitrate Aerosol Formation and Visibility Impacts in Class I Areas. Earth Tech, Inc. Extended Abstract. 12th Joint Conference on the Applications of Air Pollution Meteorology with the Air and Waste Management Association. American Meteorological Society. J5.13. Norfolk, VA.

Therefore, POSTUTIL will be used to repartition the nitric acid (HNO_3) and nitrate (NO_3) concentrations (MNITRATE = 1). With this application, the possibility of double-counting the available ammonia in the CALPUFF chemistry is avoided. A summary of the relevant POSTUTIL inputs are listed in the Table 5.0. The program model defaults are also listed for comparison. The settings that differ from the model defaults are highlighted with the reasons for the differences noted.

Table 5.0: Summary of POSTUTIL Inputs.

POSTUTIL Variable	Description	Recommended Value or Default	Value To Be Used
NSPECINP	Number of modeled species to process from CALPUFF input data files	No Default	Will vary with source
NSPECOUT	Number of modeled species to write to CALPUFF output data files	No Default	Will vary with source
MNITRATE	Repartition HNO_3/NO_2 (0 = no) {1 = yes for all sources listed}	0	1
BCKNH3	Background ammonia; same as monthly values used in CALPUFF {North Dakota data}	10	1.22, 1.23, 1.60, 1.94, 2.29, 1.63, 1.65, 1.69, 0.98, 1.04, 1.37, 1.06
MODEL.DAT	Data file containing POSTUTIL results	No Default	YYXXXPOST.DAT[a]
PSTLST	List of POSTUTIL application information	No Default	YYXXXPOST.LST

[a.] YY = Year of meteorology, XXX = 3-letter code for each BART-eligible/subject source.

The POSTUTIL results will be processed by CALPOST for the visibility calculations.

6.0 CALPOST INPUTS

For each met year, CALPOST will be run with each individual set of Class I area receptors that are within 300 km of the facility containing the BART-eligible/subject source(s). The receptors are identified by a unique NPS code, which will simplify tracking the CALPOST runs.

6.1 NATURAL BACKGROUND

CALPOST will be used to calculate the daily visibility conditions in deciviews from the estimated individual specie concentrations derived from the BART-eligible/subject source(s) emissions. The modeled deciview visibility metric will be compared to the natural background visibility conditions (delta-deciview) at the relevant Class I areas as required by the BART guidelines:[2]

> "Finally, these final BART guidelines use the natural visibility baseline for the 20 percent best visibility days for comparison to the ``cause or contribute'' applicability thresholds. We believe this estimated baseline is likely to be reasonably conservative and consistent with the goal of natural conditions."

For BART-related analyses, monthly site-specific relative humidity adjustment factors must be applied to both background (natural visibility conditions of a Class I area) and modeled sulfates and nitrates (MVISBK = 6). This method computes the extinction from speciated PM measurements using FLAG RH adjustment factor applied to observed and modeled sulfate and nitrate. The acronym FLAG is the Federal Land Managers AQRV (Air Quality Related Values) Workgroup. A different method is used to calculate visibility for major stationary source permit applications.

The "Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program", (Guidance), contains monthly site-specific relative humidity adjustment factors (f(RH)) values for all federally mandated Class I areas.[7] These long-term factors were calculated from hourly relative humidity measurements over a 10-year period (1988 – 1997); these values are given in Appendix C.

For CALPOST input, monthly background concentrations for six light extinction species are also required to define the natural background visibility conditions for each Class I area of concern. These species are ammonium sulfate, ammonium nitrate, coarse particles, organic carbon, soil dust, and elemental carbon. These concentrations will be estimated for each Class I area using a procedure adapted from the Guidance.

Default average annual aerosol concentrations have been developed based on two general geographic U.S. locations ("East" and "West".). Table 6.1A lists the estimated default natural concentrations of the aerosols for the "West" geographic location, and the corresponding dry extinction efficiency coefficients and dry particulate extinctions.[7]

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7. EPA. 2003. Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program. EPA-454/B-03-005. U.S. Environment Protection Agency. Office of Air Quality Planning and Standards. Emissions, Monitoring and Analysis Division. Air Quality Trends Analysis Group. Research Triangle Park, NC.

Table 6.1A: Default West Average Annual Natural Background Levels of Aerosol Components.[7]

Component	Average Annual Natural Background West ($\mu g/m^3$)	Dry Extinction Efficiency Coefficient (m^2/g)	Dry Particulate Matter Extinction (Mm^{-1})
Ammonium Sulfate	0.12	3.0	0.36
Ammonium Nitrate	0.10	3.0	0.30
Organic Carbon Mass	0.47	4.0	1.88
Elemental Carbon	0.02	10.0	0.20
Soil (Fine)	0.50	1.0	0.50
Coarse Mass	3.00	0.6	1.80
Total	Fine = 1.21 Coarse = 3.00		5.04

The Guidance also lists the default natural background visibility values (measured in deciviews) for all mandatory 156 Class I areas in the nation. The 10th and 90th percentile deciviews values are also included. These values correspond to the visibilities on the 20% best and 20% worse days, respectively; this information is provided in Appendix D. Although the default background visibilities were given, the corresponding aerosol concentrations were not.

Section 2.4 in the Guidance describes a method to determine the average annual natural background extinction (in Mm^{-1}) for a Class I area based on the area's general geographic location. This method also uses the Class I area's annual relative humidity correction factor, f(RH). By replacing the annual average deciview values in the procedure with the 20% best days deciview value for a particular Class I area, the aerosol concentrations for the 20% best visibility days for that area can be estimated.

For demonstration purposes, the aerosol composition of Glacier National Park (GNP) will be calculated. Since the new IMPROVE reconstruction extinction equation has not been officially adopted, the current equation will be used.

GNP 20% best days natural background visibility[7] = 2.44 dv
Annual relative humidity adjustment factor f(RH)[7] = 3.35

$$dv = 10 \ln (b_{ext}/10) \rightarrow 2.44 \text{ dv} = 10 \ln (b_{ext}/10 \text{ Mm}^{-1})$$

and with rearrangement:

$$b_{ext} = 10 \exp (dv/10) \rightarrow b_{ext} = 10 \exp (2.44/10)$$

$$\text{Therefore, } b_{ext} = 12.76 \text{ Mm}^{-1}$$

The b_{ext}, f(RH) value, and the estimated default natural concentrations of the aerosols for the "West" geographic location are inserted into the current IMPROVE reconstructed light extinction equation.

$$b_{ext} = (3)\ f(RH)\ [\text{Ammonium Sulfate}] + (3)\ f(RH)\ [\text{Ammonium Nitrate}] + (0.6)\ [\text{Coarse Mass}] + (4)\ [\text{Organic Carbon}] + (1)\ [\text{Soil}] + (10)\ [\text{Elemental Carbon}] + b_{ray}$$

$$12.76 = (3)\ (3.35)\ [0.12]\ X + (3)\ (3.35)\ [0.1]\ X + (0.6)\ [3.0]\ X + (4)\ [0.47]\ X + (1)\ [0.5]\ X + (10)\ [0.02]\ X + 10$$

The unknown variable, X, is the scaling factor to convert the default annual average natural background specie concentrations to values representing the 20% best visibility days for GNP. Solving for X produces a value of 0.419.

In this example, the background GNP concentration for ammonium sulfate on the 20% best days would be 0.050 μg/m^3 (0.419 * 0.12 μg/m^3 = 0.050 μg/m^3). Table 6.1B lists the default annual average natural background aerosol concentrations and corresponding concentrations for Glacier National Park on the 20% best visibility days.

Table 6.1B: Aerosol Levels For Default West Average Annual Natural Background And GNP 20% Best Visibility Days.

Component	**Average Annual Natural Background West (μg/m^3)**	**20% Best Days Glacier National Park (GNP) (μg/m^3)**
Ammonium Sulfate	0.12	0.050
Ammonium Nitrate	0.10	0.042
Organic Carbon Mass	0.47	0.197
Elemental Carbon	0.02	0.008
Soil (Fine)	0.50	0.209
Coarse Mass	3.00	1.256
Total	Grand Total = 4.21 Fine = 1.21 Coarse = 3.00	Grand Total = 1.762 Fine = 0.506 Coarse = 1.256

The previous table indicates that the visibility at Glacier National Park is substantially cleaner on the 20% best visibility days than the average annual natural background in the West due to lower aerosol concentrations.

This procedure will be applied to all sixteen Class I areas of concern and the resulting aerosol compositions using the current IMPROVE equation are provided in Appendix E.

6.2 98TH PERCENTILE METHODS

According the BART guidelines:[2]

> "...you should compare your "contribution" threshold against the 98th percentile of values. If the 98th percentile value from your modeling is less than your contribution threshold, then you may conclude that the source does not contribute to visibility impairment and is not subject to BART."

The BART guidelines do not specify a method for calculating the 98th percentile delta-deciview value nor does CALPOST have the ability to produce the results in this manner. CALPOST reports the number of days with a Δ dv greater than or equal to 0.5 dv for each met year.

The EPA recommends selecting the 98th percentile value from the distribution of values containing the highest modeled Δ dv value for each day from all modeled receptors at a given Class I area. The 98th percentile value can then be determined two ways:

- The 8th highest daily value for each met year modeled
- The 22nd highest daily value for all 3 met years combined

For example, for one met year, the 98th percentile can be approximated by the following: 8 days/365 total days per year * 100 ≈ 2% ≈ 98th percentile.

Both methods will be used and the highest value of the two will be compared to the contribution threshold (Δ dv ≥ 0.5 dv). If there are more than 7 days with values greater than the contribution threshold for any met year for any Class I areas, then the source is considered subject-to-BART. Since CALPOST does not automatically report these values, some sorting of the results will be required.

The contribution threshold has an implied level of precision equal to the level of precision reported by CALPOST. Specifically, the 98th percentile value will be reported to three decimal places.

The 98th percentile Δ dv will also be compared pre- and post-BART control implementation. If several BART strategies are investigated, all scenarios will be documented. Table 6.2 lists a summary of the CALPOST inputs. The program model defaults are also listed for comparison. The settings that differ from the model defaults are highlighted with the reasons for the differences noted. Inputs noted by "will vary" or "Will Vary" will change depending upon the met year.

Table 6.2: Summary of CALPOST Inputs.

CALPOST Variable	Description	Recommended Value or Default	Value To Be Used
MODDAT	Concentration output file from CALPUFF {filename will reflect the met year and source(s) involved}	MODEL.DAT	YYXXXPOST.DAT[a] (will vary)
VISDAT	Relative Humidity file	VISB.DAT	Not Used
BACKDAT	Background data file	BACK.DAT	Not Used
VSRDAT	Transmissometer/ Nephelometer hourly background light data	VSR.DAT	Not Used
CALPOST.LST	Name of CALPOST list file {filename will reflect the met year and source(s) involved}	CALPOST.LST	YYXXXZZZPOST.LST[b] (will vary)
TSPATH	Pathname for Timeseries files	Not Used	Not Used
PLPATH	Pathname for plot files	Not Used	Not Used
TSUNAM	Timeseries	Not Used	Not Used
TUNAM	Top Nth rank plot	Not Used	Not Used
XUNAM	Exceedance plot	Not Used	Not Used
EUNAM	Echo plot (specific days)	Not Used	Not Used
VUNAM	Visibility plot (daily peak summary)	Not Used	Not Used
LCFILES	Keep file names in lower case (F = upper case)	F	F
METRUN	Run period (0 = explicitly defined below; 1 = run all periods in CALPUFF data file(s))	0	0
Met Data Year 1; Repeated for Each Met Year			
ISYR	Beginning year	Can be a subset of CALPUFF Period	Will Vary
ISMO	Beginning month		1
ISDY	Beginning day		1
ISHR	Beginning hour		1

CALPOST Variable	Description	Recommended Value or Default	Value To Be Used
NHRS	Number of hours to process		Will Vary
End of Year-Specific Inputs			
NREP	Process every hour of data? (1 = every hour)	1	1
ASPEC	Species to process (ASPEC = VISIB for visibility processing)	VISIB	VISIB
ILAYER	Layer/deposition code (1 for CALPUFF concentrations)	1	1
A and B	Scaling factors of the form: X(new) = X(old) * A + B (NOT applied if A = B = 0.0)	A = 0.0 B = 0.0	A = 0.0 B = 0.0
LBACK	Add hourly background concentrations/fluxes?	F	F
LG	Gridded receptors processed?	F	F
LD	Discrete receptors processed?	F	T
LCT	CTSG Complex terrain receptors processed?	F	F
LDRING	Report results by receptor ring?	F	F
NDRECP	Select specific receptors (-1 = process all)	-1	-1
IBGRID	X index of LL corner (Entire grid is processed if IBGRID=JBGRID=IEGRID=JEGRID=-1) {Class I area receptors are discrete}	-1	Not Used
JBGRID	Y index of LL corner (-1 = use all gridded receptors) {Class I area receptors are discrete}	-1	Not Used
IEGRID	X index of UR corner (-1 = use all gridded receptors) {Class I area receptors are discrete}	-1	Not Used
JEGRID	Y index of UR corner (-1 = use all gridded receptors) {Class I area receptors are discrete}	-1	Not Used
NGONOFF	Number of gridded receptor rows to identify specific gridded receptors to process	0	0
NGXRECP	Specific gridded receptors included/excluded (1 = gridded receptors processed)	1	1
RHMAX	Maximum relative humidity (%) used in particle growth curve {not used with Method 6}	95	Not Used

<table>
<tr><th>CALPOST Variable</th><th>Description</th><th>Recommended Value or Default</th><th>Value To Be Used</th></tr>
<tr><td>LVSO4</td><td>Include modeled SULFATE in computing the light extinction?</td><td>T</td><td>T</td></tr>
<tr><td>LVNO3</td><td>Include NITRATE?</td><td>T</td><td>T</td></tr>
<tr><td>LVOC</td><td>Include ORGANIC CARBON?</td><td>T</td><td>T</td></tr>
<tr><td>LVPMC</td><td>Include COARSE PARTICLES?</td><td>T</td><td>T</td></tr>
<tr><td>LVPMF</td><td>Include FINE PARTICLES?</td><td>T</td><td>T</td></tr>
<tr><td>LVEC</td><td>Include ELEMENTAL CARBON?</td><td>T</td><td>T</td></tr>
<tr><td>LVBK</td><td>Include background when ranking for TOP-N, TOP-50, and Exceedance tables?</td><td>T</td><td>F</td></tr>
<tr><td>SPECPMC</td><td>Species name used for COARSE particulates in MODEL.DAT file</td><td>PMC</td><td>PMC</td></tr>
<tr><td>SPECPMF</td><td>Species name used for FINE particulates in MODEL.DAT file</td><td>PMF</td><td>PMF</td></tr>
<tr><td colspan="4">EXAMPLE:
<pre>
Extinction Efficiency (1/Mm per ug/m**3)

    MODELED particulate species:
               PM COARSE   (EEPMC) -- Default: 0.6 ! EEPMC   = 0.6 !
               PM FINE   (EEPMF) -- Default: 1.0 ! EEPMF   = 1.0 !
    BACKGROUND particulate species:
               PM COARSE   (EEPMCBK) -- Default: 0.6 ! EEPMCBK = 0.6 !
    Other species:
              AMMONIUM SULFATE (EESO4) -- Default: 3.0 ! EESO4   = 3.0 !
              AMMONIUM NITRATE (EENO3) -- Default: 3.0 ! EENO3   = 3.0 !
              ORGANIC CARBON   (EEOC) -- Default: 4.0 ! EEOC   = 4.0 !
              SOIL   (EESOIL)-- Default: 1.0 ! EESOIL = 1.0 !
              ELEMENTAL CARBON (EEEC) -- Default: 10. ! EEEC   = 10.0 !
</pre></td></tr>
<tr><td>MVISBK</td><td>Method used for background light extinction {for BART-related modeling, Method 6 should be used}</td><td>2</td><td>6</td></tr>
<tr><td>BEXTBK</td><td>Background light extinction</td><td>0.0</td><td>0.0</td></tr>
<tr><td>RHFRAC</td><td>Percentage of particles affected by relative humidity {used if MVISBK = 1}</td><td>0.0</td><td>Not Used</td></tr>
<tr><td>RHFAC</td><td>Monthly relative humidity adjustment factors for adjusting extinction coefficients</td><td>No Default</td><td>Will vary with Class I Area (list of 12 values)</td></tr>
<tr><td>BKSO4</td><td>Monthly background concentrations of ammonium sulfate (μg/m^3)</td><td>No Default</td><td>Will vary with Class I Area (list of 12 values)</td></tr>
</table>

CALPOST Variable	Description	Recommended Value or Default	Value To Be Used
BKNO3	Monthly background concentrations of ammonium nitrate ($\mu g/m^3$)	No Default	Will vary with Class I Area (list of 12 values)
BKPMC	Monthly background concentrations of coarse particulates ($\mu g/m^3$)	No Default	Will vary with Class I Area (list of 12 values)
BKOC	Monthly background concentrations of organic carbon ($\mu g/m^3$)	No Default	Will vary with Class I Area (list of 12 values)
BKSOIL	Monthly background concentrations of soil ($\mu g/m^3$)	No Default	Will vary with Class I Area (list of 12 values)
BKEC	Monthly background concentrations of elemental carbon ($\mu g/m^3$)	No Default	Will vary with Class I Area (list of 12 values)
BEXTRAY	Extinction due to Rayleigh scattering (1/Mm)	10.0	10.0
LDOC	Print documentation image?	F	F
IPRTU	Output units for concentration and deposition {Visibility: extinction expressed in 1/Megameters and IPRTU is ignored}	3 = $\mu g/m^3$, $\mu g/m^2/s$	Not Used
L1HR	1-hr averages reported {not interested in 1-hr values}	T	F
L3HR	3-hr averages reported {not interested in 3-hr values}	T	F
L24HR	24-hr averages reported	T	T
LRUNL	Run-length averages reported {not interested in these averages}	T	F
NAVG	User-specified averaging time in hours	0	0
Visibility: daily visibility tabulations are always reported for the selected receptors when ASPEC = VISIB.			
LT50	Top 50 table for each averaging time selected [List file only]	T	T
LTOPN	Top 'N' table for each averaging time selected [List file or Plot file]	F	F
NTOP	Number of 'Top-N' values at each receptor selected (<=4)	4	4
ITOP(4) array	Specific ranks of 'Top-N' values reported (NTOP values must be entered)	1, 2, 3, 4	1,2,3,4
LEXCD	Threshold exceedance counts for each receptor and each averaging time selected [List file or Plot file]	F	F

CALPOST Variable	Description	Recommended Value or Default	Value To Be Used
THRESH1	Threshold for 1-hr averages (-1.0 = no threshold)	-1.0	-1.0
THRESH3	Threshold for 3-hr averages (-1.0 = no threshold)	-1.0	-1.0
THRESH24	Threshold for 24-hr averages (-1.0 = no threshold)	-1.0	-1.0
THRESHN	Threshold for NAVG-hr averages (-1.0 = no threshold)	-1.0	-1.0
NDAY	Accumulation period (days)	0	0
NCOUNT	Number of exceedances allowed	1	0
LECHO	Echo option	F	F
LTIME	Timeseries option	F	F
IECHO(366)	Days selected for output (366 values must be entered)	366*0	366*0
LPLT	Generate Plot file output in addition to writing tables to list file?	F	F
LGRD	Use GRID format rather than DATA format, when available?	F	F
LDEBUG	Output selected information to List file for debugging?	F	F

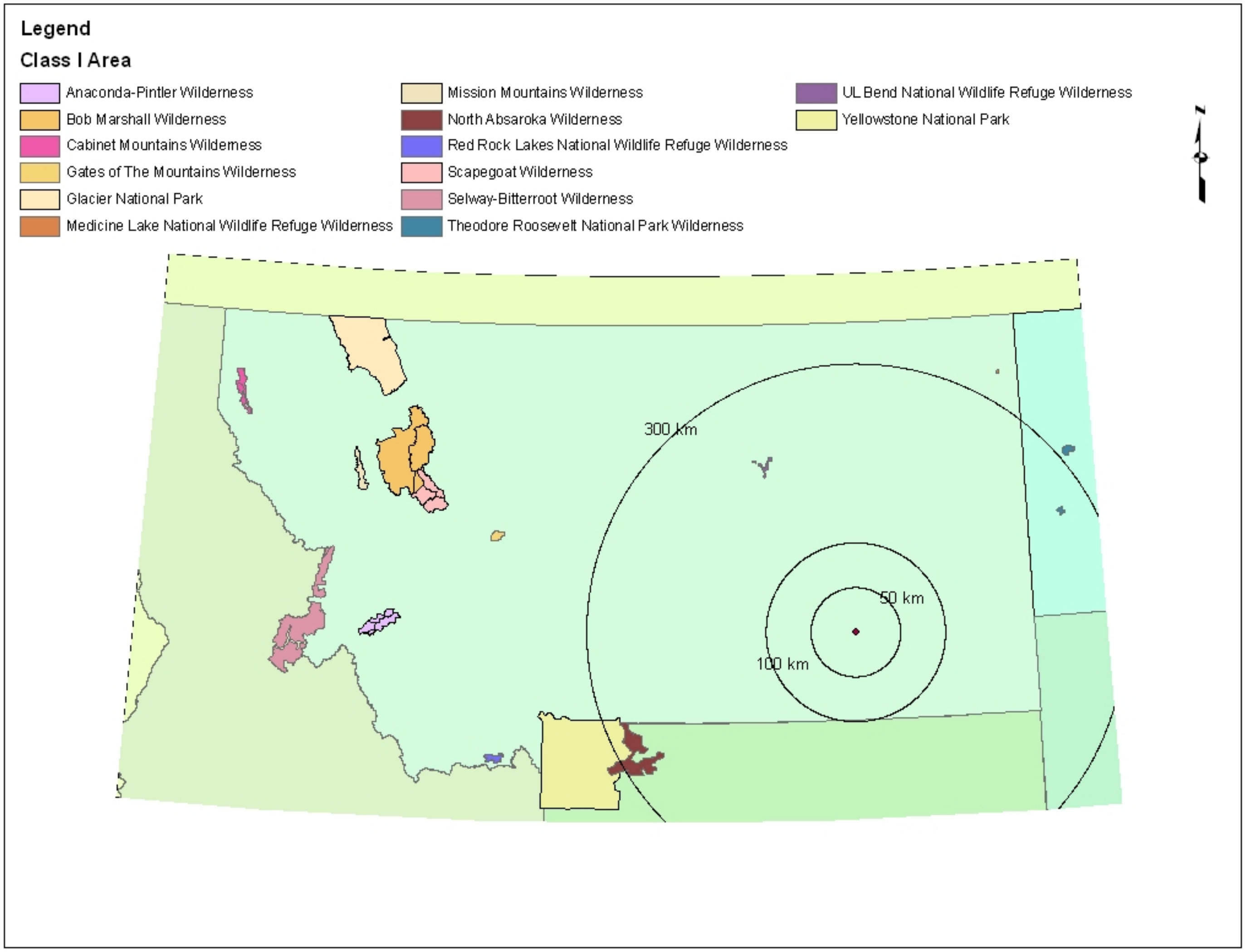
[a.] YY = Year of meteorology; XXX = 3-letter code for each BART-eligible/subject source.
[b.] ZZZ = unique Class I area NPS code.

7.0 RESULTS

Since an industrial facility may contain more than one subject-to-BART source, the results will be presented in sections according to the facility name in alphabetical order. Within each of those sections, the BART-eligible modeling results for the emission unit(s) will be addressed first, then the individual subject-to-BART analysis.

For each facility, a map will be created of the primary modeling domain with all sixteen significant Class I areas. Circles of 50, 100, and 300 kilometers centered on the location of the facility will be included to delineate the maximum distance acceptable (300 km) for characterizing air pollution transport by CALPUFF. In addition, the WRAP has developed emissions reports based on 50 km buffer zones surrounding each western federal mandatory Class I area (http://www.wrapair.org/forums/class1/near/htmlfiles/mainmap1.html). Figure 7.0A displays an example figure for a facility located in the Colstrip area and the three reference circles.

Figure 7.0A: Example Figure Showing 50, 100, and 300 Km Reference Circles Around A Colstrip Facility.



The BART-eligible results will be tabulated for each meteorological year similar to Table 7.0A. In the following tables and graphs, two fictitious BART-eligible sources at one facility affected four Class I areas.

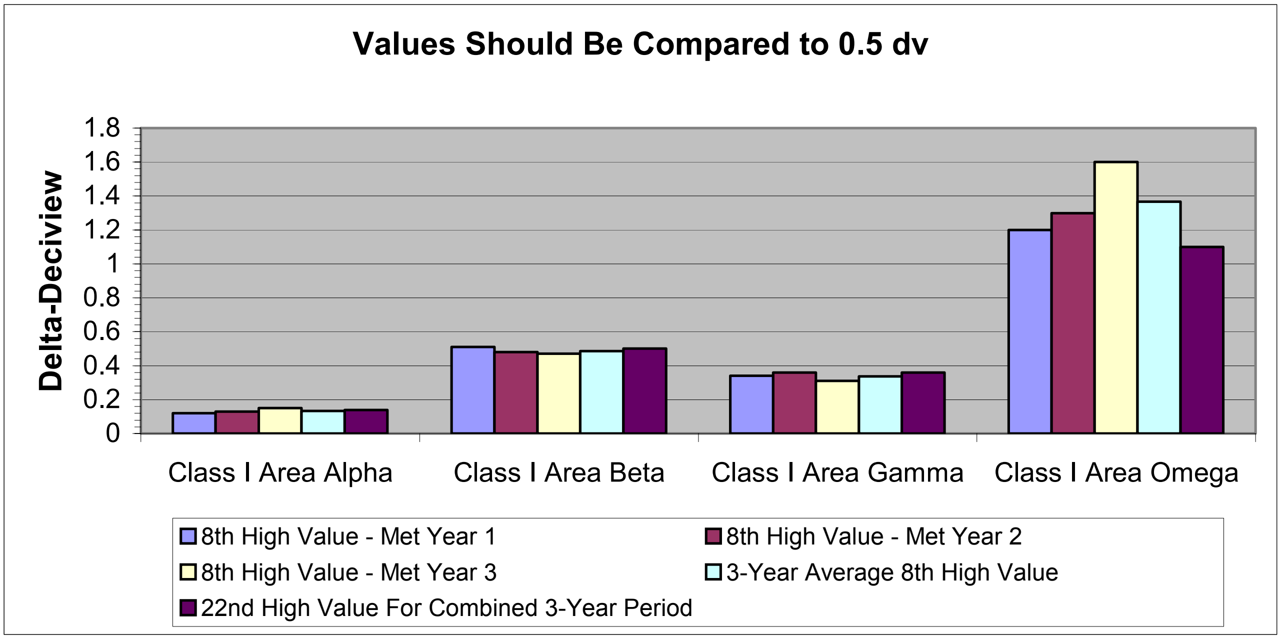
Table 7.0A: Example Table of 98th Percentile Daily Delta-Deciviews From Two BART-Eligible Sources Compared Against Natural Background Visibility Conditions To “Contribution Threshold”.

FACILITY NAME BART-Eligible Source(s) MDEQ Code(s)	**98th Percentile Daily Change In Visibility From BART-Eligible Source Compared To Natural Background Conditions**							
	8th High Delta-Deciview Value (dv)							**22nd High Delta-Deciview Value From 3-Year Average Modeling Period**
	Met Year 1		**Met Year 2**		**Met Year 3**		**3-Year Average**	
Federal Mandatory Class I Area	**Δ dv**	**Number of Days ≥ 0.5 dv**	**Δ dv**	**Number of Days ≥ 0.5 dv**	**Δ dv**	**Number of Days ≥ 0.5 dv**	**Δ dv**	
Class I Area Alpha								
Class I Area Beta								
Class I Area Gamma								
Class I Area Omega								

a. Δ is the symbol for change.

These results will also be represented by bar charts as shown in Figure 7.0B.

Figure 7.0B: Example Graph For Two BART-Eligible Sources Comparing 98th Percentile Daily Change in Visibility Values In Four Class I Areas.



The individual subject-to-BART sources will be presented in a similar manner, but on an air pollutant emissions basis (SO_2, NO_x, and PM_{10}). The days and receptor locations of the 98th percentile change events will also be tabulated.

The results will also be summarized in a table of the highest Δ dv 98th percentile values from all Montana subject-to-BART sources, on an individual pollutant basis, as shown in Table 7.0B.

Table 7.0B: Example Summary Table of 98th Percentile Daily Delta-Deciview Contribution From All Montana BART-Subject Sources Compared Against Natural Background Visibility Conditions.

BART-Subject Source	98th Percentile Delta-Deciview Contribution (Δ dv)	Impacted Class I Area	Receptor	Critical Met Period	Day
AAA	1.533	Class I Area Alpha			
BBB	0.499	Class I Area Gamma			

[a.] Δ is the symbol for change.

Another method is to display the results by individual Class I area by air pollutant similar to Table 7.0C.

Table 7.0C: Example NO_x Summary Table of 98th Percentile Daily Delta-Deciview Contribution From BART-Subject Sources Compared Against Class I Area Alpha Natural Background Visibility Conditions.

Pollutant: NO_x Class I Area: Class I Area Alpha						
BART-Subject Source	**98th Percentile Delta-Deciview Contribution (Δ dv)**	**Daily Emissions (lb/day)**	**Distance To Impacted Class I Area (km)**	**Receptor**	**Critical Met Period**	**Day**
AAA[a]						
BBB						
CCC						

[a.] Arbitrary code.
[b.] Δ is the symbol for change.

Summary tables of the highest 98th percentile daily Δ dv from the subject-to-BART sources, regardless of the air pollutant, will also be developed analogous to Table 7.0D.

Table 7.0D: Example NO_x Summary Table of 98th Percentile Daily Delta-Deciview Contribution From BART-Subject Sources Compared Against Class I Area Alpha Natural Background Visibility Conditions.

BART-Subject Source	**Pollutant: All Class I Area: Class I Area Alpha**						
	Pollutant	**98th Percentile Delta-Deciview Contribution (Δ dv)**	**Daily Emissions (lb/day)**	**Distance To Impacted Class I Area (km)**	**Receptor**	**Critical Met Period**	**Day**
AAA[a]							
BBB							
CCC							

[a.] Arbitrary code.
[b.] Δ is the symbol for change.

APPENDIX A:

Values For f(RH) Determined From The Growth Of Ammonium Sulfate[8]

[8] EPA. 2003. Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program. EPA-454/B-03-005. U.S. Environment Protection Agency. Office of Air Quality Planning and Standards. Emissions, Monitoring and Analysis Division. Air Quality Trends Analysis Group. Research Triangle Park, NC.

Table A-l Values for f(RH) determined from the growth of ammonium sulfate

RH	f(RH)	RH	f(RH)	RH	f(RH)
1	1.00	34	1.00	67	2.03
2	1.00	35	1.00	68	2.08
3	1.00	36	1.00	69	2.14
4	1.00	37	1.02	70	2.19
5	1.00	38	1.04	71	2.25
6	1.00	39	1.06	72	2.31
7	1.00	40	1.08	73	2.37
8	1.00	41	1.10	74	2.43
9	1.00	42	1.13	75	2.50
10	1.00	43	1.15	76	2.56
11	1.00	44	1.18	77	2.63
12	1.00	45	1.20	78	2.70
13	1.00	46	1.23	79	2.78
14	1.00	47	1.26	80	2.86
15	1.00	48	1.28	81	2.94
16	1.00	49	1.31	82	3.03
17	1.00	50	1.34	83	3.12
18	1.00	51	1.37	84	3.22
19	1.00	52	1.41	85	3.33
20	1.00	53	1.44	86	3.45
21	1.00	54	1.47	87	3.58
22	1.00	55	1.51	88	3.74
23	1.00	56	1.54	89	3.93
24	1.00	57	1.58	90	4.16
25	1.00	58	1.62	91	4.45
26	1.00	59	1.66	92	4.84
27	1.00	60	1.70	93	5.37
28	1.00	61	1.74	94	6.16
29	1.00	62	1.79	95	7.40
30	1.00	63	1.83	96	9.59
31	1.00	64	1.88	97	14.1
32	1.00	65	1.93	98	26.4
33	1.00	66	1.98		

APPENDIX B:

Precipitation Stations

APPENDIX B: Precipitation Stations[a]

Station	State	WBAN[b] ID	Grid Coordinates		Coordinates		Time Zone
			X	Y	Latitude	Longitude	
Alzada	MT	240165	1001618	99778	45.03	104.40	7
Ashland Ranger STN	MT	240330	851854	155230	45.60	106.27	7
Augusta	MT	240364	383102	362898	47.48	112.38	7
Baylor	MT	240554	822339	495460	48.67	106.48	7
Billings WB AP	MT	240807	675379	172724	45.80	108.53	7
Boulder	MT	241008	398030	223409	46.23	112.12	7
Bozeman 6 W EXP Farm	MT	241047	471481	159167	45.67	111.15	7
Bredette	MT	241088	912067	486260	48.55	105.27	7
Broadus	MT	241127	920624	139541	45.43	105.40	7
Browning	MT	241202	340374	485890	48.57	113.02	7
Butte 8 S	MT	241309	365796	187883	45.90	112.52	7
Clark Canyon Dam	MT	241781	335944	89012	45.00	112.85	7
Cohagen	MT	241875	818655	315153	47.05	106.62	7
Content 3 SSE	MT	241984	745493	416284	47.98	107.55	7
Cooke City 2 W	MT	241995	562956	85698	45.02	109.97	7
Cut Bank FAA Airport	MT	242173	388415	487267	48.60	112.37	7
Darby	MT	242221	238757	207472	46.02	114.17	7
Dillon 9 SSE	MT	242414	355990	97084	45.08	112.60	7
Divide 2 NW	MT	242421	345040	174264	45.77	112.78	7
Dodson 11 N	MT	242441	695949	478628	48.55	108.20	7
Drummond Aviation	MT	242500	320957	275417	46.67	113.15	7
Dutton 6 E	MT	242584	444426	402091	47.85	111.58	7
Ekalaka	MT	242689	985406	193377	45.88	104.53	7
Elkhorn Hot Springs	MT	242719	317089	142131	45.47	113.12	7
Essex	MT	242812	294462	455855	48.28	113.62	7
Fort Peck Power Plant	MT	243176	831084	423492	48.02	106.40	7
Gibbons Pass	MT	243479	253737	170986	45.70	113.95	7
Gibson Dam	MT	243489	354303	377374	47.60	112.77	7
Glasgow WSO Airport	MT	243558	813875	445080	48.22	106.62	7
Glendive	MT	243581	962424	327750	47.10	104.72	7
Great Falls WSCMO Airport	MT	243751	459148	360591	47.48	111.37	7
Havre WSO AP	MT	243996	580071	477866	48.55	109.77	7
Hebgen Dam	MT	244038	455386	70606	44.87	111.33	7
Helena WB AP	MT	244055	408590	264192	46.60	112.00	7
Hilger	MT	244143	611348	333365	47.25	109.35	7
Holter Dam	MT	244241	408488	308658	47.00	112.02	7
Hungry Horse Dam	MT	244328	266758	465174	48.35	114.00	7
Iliad	MT	244368	579035	394507	47.80	109.78	7

APPENDIX B: Precipitation Stations (continued)

Station	State	WBAN ID	Grid Coordinates		Coordinates		Time Zone
			X	Y	Latitude	Longitude	
Ismay	MT	244442	960363	260843	46.50	104.80	7
Joplin	MT	244512	506301	480815	48.57	110.77	7
Kalispell Glacier AP	MT	244558	246450	460809	48.30	114.27	7
Lakeview	MT	244820	417373	41589	44.60	111.80	7
Lavina	MT	244904	643891	227968	46.30	108.93	7
Lewistown 2 SW	MT	244983	603797	311134	47.05	109.45	7
Libby 1 NE Ranger STN	MT	245015	154079	478330	48.40	115.53	7
Lima	MT	245030	355685	49269	44.65	112.58	7
Lincoln Ranger STN	MT	245040	360410	304841	46.95	112.65	7
Livingston FAA AP	MT	245086	526041	161595	45.70	110.45	7
Lodge Grass	MT	245106	767017	118973	45.30	107.37	7
Logan	MT	245122	450250	182991	45.88	111.43	7
Lolo Hot Springs 2 NE	MT	245146	216913	290083	46.75	114.52	7
Martinsdale 3 NNW	MT	245387	536324	250365	46.50	110.33	7
Millegan	MT	245706	457955	310606	47.03	111.37	7
Missoula WSO AP	MT	245745	250099	308078	46.93	114.10	7
Molt 7 SW	MT	245791	641210	169064	45.77	108.97	7
Heihart 8 NNW	MT	246008	502803	311927	47.05	110.78	7
Ovando	MT	246302	324286	314190	47.02	113.13	7
Philipsburg Ranger STN	MT	246472	307612	237124	46.32	113.30	7
Plains Ranger STN	MT	246562	194973	371714	47.47	114.88	7
Pleasant Valley 4 SE	MT	246580	200521	441510	48.10	114.87	7
Polebridge	MT	246615	249630	512964	48.77	114.27	7
Reedpoint	MT	246946	596109	163370	45.72	109.55	7
Round Butte 1 NNE	MT	247204	240490	375439	47.53	114.28	7
Russell	MT	247258	483056	425648	48.07	111.07	7
St Mary	MT	247292	311161	507316	48.75	113.43	7
St Regis Clark Fork	MT	247316	178597	353926	47.30	115.08	7
Scobey 4 NW	MT	247425	894991	516535	48.83	105.48	7
Seeley Lake Ranger STN	MT	247448	295829	337828	47.22	113.52	7
Silver Star	MT	247610	383533	162767	45.68	112.28	7
Stevensville	MT	247894	247426	262606	46.52	114.10	7
Summit	MT	247978	314687	459277	48.32	113.35	7
Swan Lake	MT	248087	276694	416744	47.92	113.83	7
Swift Dam	MT	248101	351004	440916	48.17	112.85	7
Terry 21 NNW	MT	248169	903510	321106	47.07	105.50	7
Townsend 12 ENE	MT	248329	463073	234919	46.35	111.28	7
Vananda 5 ESE	MT	248511	799875	240013	46.38	106.90	7
Westby	MT	248777	999470	527314	48.87	104.05	7

APPENDIX B: Precipitation Stations (continued)

Station	State	WBAN ID	Grid Coordinates		Coordinates		Time Zone
			X	Y	X	Y	
West Glacier	MT	248809	269191	481736	48.50	113.98	7
West Yellowstone USFS	MT	248866	473105	47984	44.67	111.10	7
White Sulphur Springs	MT	248927	491125	254347	46.53	110.92	7
Winnett 8 ESE	MT	249052	700422	300868	46.95	108.18	7
Wisdom	MT	249067	292160	160022	45.62	113.45	7
Yellowtail Dam	MT	249240	723069	120158	45.32	107.93	7
Zortman	MT	249900	672462	408254	47.92	108.53	7
Bonners Ferry	ID	101079	100164	516219	48.70	116.30	8
Cambridge 2 NE	ID	101410	34355	62448	44.58	116.63	7
Cascade 1 NW	ID	101514	79792	52891	44.53	116.05	7
Clarkia Ranger Station	ID	101831	86246	330016	47.02	116.27	8
Cottonwood 2 WSW	ID	102159	68271	221179	46.03	116.38	8
Council	ID	102187	51653	77631	44.73	116.43	7
Dixie	ID	102575	134394	162233	45.55	115.47	8
Dubois Experimental STN	ID	102707	384283	3718	44.25	112.20	7
Dworshak Fish Hatchery	ID	102845	78966	272659	46.50	116.30	8
Elk City Ranger STN	ID	102875	139861	193017	45.83	115.43	8
Elk River 1 S	ID	102892	90693	301755	46.77	116.18	8
Enaville	ID	102966	93020	390769	47.57	116.25	8
Fenn Ranger Station	ID	103143	132882	223637	46.10	115.55	8
Leadore	ID	105169	293230	55380	44.68	113.37	7
McCall	ID	105708	77717	94335	44.90	116.12	7
Middle Fork Lodge	ID	105897	162934	67653	44.72	115.02	7
Moscow 5 NE	ID	106148	34749	310151	46.80	116.92	8
Mullan	ID	106230	125850	376878	47.47	115.80	8
Pierce	ID	107046	117191	269455	46.50	115.80	8
Plummer 3 WSW	ID	107188	36453	368025	47.32	116.97	8
Porthill 1 SW	ID	107269	88479	550740	49.00	116.50	8
Prichard 4 N	ID	107358	114629	405668	47.72	115.98	8
Sandpoint EXP Station	ID	108137	76162	471475	48.28	116.57	8
Yellow Pine 7 S	ID	109951	125510	77097	44.78	115.50	7
Yellowpine Bar	ID	109963	151520	160950	45.55	115.25	6
Ambrose 3 N	ND	320189	1040790	544843	49.00	103.47	6
Bowbells	ND	320961	1131794	530257	48.80	102.25	6
Bowman Court House	ND	320995	1071818	232918	46.18	103.38	7
Dickinson EXP STN	ND	322188	1109784	314062	46.88	102.80	7
Dunn Center 2 SW	ND	322365	1116607	367069	47.35	102.65	7
Glen Ullin	ND	323496	1184778	314271	46.82	101.82	7
Hazen 1 S	ND	324088	1194823	366634	47.28	101.62	7

APPENDIX B: Precipitation Stations (continued)

Station	State	WBAN ID	Grid Coordinates		Coordinates		Time Zone
			X	Y	X	Y	
Hettinger EXP Station	ND	324180	1129708	217656	46.00	102.65	7
McGregor	ND	325720	1083902	503697	48.60	102.93	6
Minot Experiment STN	ND	325993	1208440	468580	48.18	101.30	6
Mott	ND	326155	1152925	261016	46.37	102.30	7
Raub 5 NNE	ND	327405	1158468	421120	47.80	102.03	6
Richardton Abbey	ND	327530	1146207	317298	46.88	102.32	7
Riverdale	ND	327585	1212593	393032	47.50	101.35	6
Trotters 3 SSE	ND	328812	1023070	351818	47.28	103.90	7
Watauga S Dakota 8 N	ND	329219	1212733	227744	46.02	101.57	7
Williston WSO	ND	329425	1035942	453045	48.18	103.63	6
Buffalo	SD	391114	28815	173449	45.58	103.55	7
Camp Crook	SD	391294	1851	6308	45.55	103.98	7
Faith	SD	392852	1063796	165438	45.03	102.03	7
Isabel	SD	394268	1230826	158117	45.38	101.43	7
Lemmon	SD	394864	1167448	213272	45.93	102.17	7
McIntosh 6 SE	SD	395381	1235146	214423	45.88	101.30	7
Milesville 8 NE	SD	395544	1229467	63019	44.53	101.57	7
Pactola Dam	SD	396427	1082128	-1476	44.07	103.48	7
Plainview 4 SSW	SD	396636	1180986	60518	44.55	102.18	7
Rapid City WB ARPT 8 ESE	SD	396937	1115075	-1083	44.05	103.07	7
Spearfish	SD	397882	1047517	43882	44.50	103.87	7
Zeona 10 SSW	SD	399537	1111272	112370	45.07	103.00	7
Buffalo	WY	481165	824901	15166	44.35	106.68	7
Lake Yellowstone	WY	485345	528465	33761	44.55	110.40	7
Moorcroft	WY	486395	963262	12778	44.27	104.95	7
Powell Field STN	WY	487388	659368	59198	44.78	108.75	7
Recluse	WY	487545	900848	62879	44.75	105.70	7
Sheridan WB AP	WY	488155	800273	61038	44.77	106.97	7
Story	WY	488626	806550	39001	44.57	106.90	7
Ten Sleep 4 NE	WY	488852	766727	-17799	44.07	107.42	7

[a] Information was provided with the Bee- Line Software Professional CALPUFF (Version 2.18.0) software.
[b] WBAN = Weather Bureau Army Navy.

APPENDIX C:

Monthly Site-Specific f(RH) Values For All National 156 Federally Mandated Class I Areas[9]

[9]. EPA. 2003. Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program. EPA-454/B-03-005. U.S. Environment Protection Agency. Office of Air Quality Planning and Standards. Emissions, Monitoring and Analysis Division. Air Quality Trends Analysis Group. Research Triangle Park, NC.

APPENDIX C: Monthly Site-Specific f(RH) Values For All National 156 Federally Mandated Class I Areas

Monthly Site-Specific f(RH) Values for Each Mandatory Federal Class I Area, Based on the Centroid of the Area (Supplemental Information)

Class I Area	Site Name	Map ID	Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Acadia	Acadia	1	ACAD1	ME	44.37	68.26	3.3	2.9	2.8	3.4	3.1	3.0	3.4	3.8	4.0	3.8	3.6	3.5
Agua Tibia	Agua Tibia	100	AGTI1	CA	33.41	116.98	2.4	2.4	2.4	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.1	2.2
Alpine Lakes	Snoqualmie Pass	80	SNPA1	WA	47.42	121.42	4.3	3.8	3.5	3.9	2.9	3.2	2.9	3.1	3.3	3.9	4.5	4.5
Anaconda - Pintler	Sula	71	SULA1	MT	45.98	113.42	3.3	2.9	2.5	2.4	2.4	2.3	2.0	1.9	2.1	2.5	3.2	3.3
Ansel Adams	Kaiser	110	KAIS1	CA	37.65	119.20	3.0	2.7	2.4	2.1	1.9	1.7	1.6	1.6	1.6	1.8	2.3	2.7
Arches	Canyonlands	50	CANY1	UT	38.64	109.58	2.6	2.3	1.8	1.6	1.6	1.3	1.4	1.5	1.6	1.6	2.0	2.3
Badlands	Badlands	59	BADL 1	SD	43.74	101.94	2.6	2.7	2.6	2.4	2.8	2.7	2.5	2.4	2.2	2.3	2.7	2.7
Bandelier	Bandelier	33	BAND1	NM	35.78	106.27	2.2	2.1	1.8	1.6	1.6	1.4	1.7	2.1	1.9	1.7	2.0	2.2
Bering Sea (a)					60.45	172.79												
Big Bend	Big Bend	31	BIBE1	TX	29.31	103.19	2.0	1.9	1.6	1.5	1.6	1.6	1.7	2.0	2.1	1.9	1.8	1.9
Black Canyon of the Gunnison	Weminuche	55	WEMI1	CO	38.58	107.70	2.4	2.2	1.9	1.9	1.9	1.6	1.7	1.9	2.0	1.8	2.1	2.3
Bob Marshall	Monture	73	MONT1	MT	47.75	113.38	3.6	3.1	2.8	2.6	2.7	2.7	2.3	2.2	2.6	2.9	3.5	3.5
Bosque del Apache	Bosque del Apache	38	BOAP1	NM	33.79	106.83	2.1	1.9	1.6	1.4	1.4	1.3	1.8	2.0	1.9	1.6	1.8	2.2
Boundary Waters Canoe Area	Boundary Waters	23	BOWA1	MN	47.95	91.50	3.0	2.6	2.7	2.4	2.3	2.9	3.1	3.4	3.5	2.8	3.2	3.2
Breton	Breton	20	BRET1	LA	29.73	88.88	3.7	3.5	3.7	3.6	3.8	4.0	4.3	4.3	4.2	3.7	3.7	3.7
Bridger	Bridger	65	BRID1	WY	42.98	109.76	2.5	2.4	2.3	2.2	2.1	1.8	1.5	1.5	1.7	2.0	2.4	2.4
Brigantine	Brigantine	5	BRIG1	NJ	39.46	74.45	2.8	2.6	2.7	2.6	3.0	3.2	3.4	3.7	3.6	3.3	2.9	2.8
Bryce Canyon	Bryce Canyon	49	BRCA1	UT	37.62	112.17	2.6	2.4	1.9	1.6	1.5	1.3	1.3	1.5	1.5	1.6	2.0	2.4
Cabinet Mountains	Cabinet Mountains	75	CABI1	MT	48.21	115.71	3.8	3.3	2.9	2.6	2.7	2.7	2.3	2.2	2.6	3.0	3.7	3.9
Caney Creek	Caney Creek	29	CACR1	AR	34.41	94.08	3.4	3.1	2.9	3.0	3.6	3.6	3.4	3.4	3.6	3.5	3.4	3.5
Canyonlands	Canyonlands	50	CANY1	UT	38.46	109.82	2.6	2.3	1.7	1.6	1.5	1.2	1.3	1.5	1.6	1.6	2.0	2.3
Cape Romain	Cape Romain	15	ROMA1	SC	32.94	79.66	3.3	3.0	2.9	2.8	3.2	3.7	3.6	4.1	4.0	3.7	3.4	3.2
Capitol Reef	Capitol Reef	52	CAPI1	UT	38.36	111.05	2.7	2.4	2.0	1.7	1.6	1.4	1.4	1.6	1.6	1.7	2.1	2.5
Caribou	Lassen Volcanic	90	LAV01	CA	40.50	121.18	3.7	3.1	2.8	2.5	2.4	2.2	2.1	2.1	2.2	2.4	3.0	3.4
Carlsbad Caverns	Guadalupe Mountains	32	GUM01	TX	32.14	104.48	2.1	2.0	1.6	1.5	1.6	1.6	1.8	2.1	2.2	1.8	1.9	2.1
Chassahowitzka	Chassahowitzka	18	CHAS1	FL	28.75	82.55	3.8	3.5	3.4	3.2	3.3	3.9	3.9	4.2	4.1	3.9	3.7	3.9
Chiricahua NM	Chiricahua	39	CHIR1	AZ	32.01	109.39	2.0	2.0	1.6	1.3	1.3	1.1	1.8	2.1	1.8	1.5	1.6	2.2
Chiricahua W	Chiricahua	39	CHIR1	AZ	31.84	109.27	2.0	1.9	1.6	1.2	1.3	1.1	1.8	2.1	1.8	1.5	1.6	2.2
Cohutta	Cohutta	12	COHU1	GA	34.92	84.58	3.3	3.1	3.0	2.8	3.4	3.8	4.0	4.2	4.2	3.8	3.4	3.5
Crater Lake	Crater Lake	86	CRLA1	OR	42.90	122.13	4.6	3.9	3.7	3.4	3.2	3.0	2.8	2.9	3.1	3.6	4.6	4.6
Craters of the Moon	Craters of the Moon	69	CRM01	ID	43.47	113.55	3.1	2.7	2.3	2.0	2.0	1.8	1.4	1.4	1.6	2.0	2.8	3.0
Cucamonga	San Gabriel	93	SAGA1	CA	34.25	117.57	2.5	2.4	2.4	2.2	2.1	2.1	2.1	2.2	2.2	2.2	2.1	2.2
Denali	Denali	102	DENA1	AK	63.72	148.97	2.5	2.3	2.1	1.9	1.9	2.2	2.5	3.0	2.8	2.9	3.0	3.1
Desolation	Bliss	95	BLIS1	CA	38.98	120.12	3.2	2.8	2.4	2.0	1.8	1.6	1.5	1.6	1.7	1.9	2.4	3.0
Diamond Peak	Crater Lake	86	CRLA1	OR	43.53	122.10	4.5	4.0	3.6	3.7	3.2	3.1	2.9	2.9	3.1	3.7	4.6	4.6
Dolly Sods	Dolly Sods	8	DOS01	WV	39.11	79.43	3.0	2.8	2.8	2.6	3.1	3.4	3.5	3.9	3.9	3.3	3.0	3.1
Dome Land	Dome Land	109	DOME1	CA	35.70	118.19	2.5	2.3	2.2	1.9	1.8	1.8	1.8	1.8	1.8	1.9	2.0	2.2
Eagle Cap	Starkey	76	STAR1	OR	45.10	117.29	3.8	3.2	2.5	2.1	2.0	1.9	1.6	1.6	1.6	2.3	3.4	4.0
Eagles Nest	White River	56	WHRI1	CO	39.69	106.25	2.2	2.2	2.0	2.0	2.1	1.9	1.8	2.0	2.0	1.9	2.1	2.1

Table A-3 Monthly Site-Specific f(RH) Values for Each Mandatory Federal Class I Area, Based on the Centroid of the Area (Supplemental Information)

Class I Area	Site Name	Map ID	Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Emigrant	Yosemite	96	YOSE1	CA	38.20	119.75	3.2	2.8	2.5	2.1	1.9	1.7	1.5	1.6	1.6	1.9	2.4	2.9
Everglades	Everglades	19	EVER1	FL	25.39	80.68	2.7	2.6	2.6	2.4	2.4	2.7	2.6	2.9	3.0	2.8	2.6	2.7
Fitzpatrick	Bridger	65	BRID1	WY	43.27	109.57	2.5	2.3	2.2	2.1	2.1	1.8	1.5	1.5	1.7	2.0	2.4	2.4
Flat Tops	White River	56	WHRI1	CO	39.97	107.25	2.3	2.2	2.0	2.0	2.0	1.8	1.7	1.9	1.9	1.8	2.2	2.2
Galiuro	Chiricahua	39	CHIR1	AZ	32.56	110.32	2.0	1.8	1.5	1.2	1.2	1.1	1.5	1.8	1.6	1.5	1.6	2.1
Gates of the Mountains	Gates of the Mountains	74	GAM01	MT	46.87	111.81	2.9	2.6	2.4	2.3	2.3	2.3	2.0	1.9	2.1	2.4	2.8	2.8
Gearhart Mountain	Crater Lake	86	CRLA1	OR	42.49	120.85	4.0	3.4	3.1	2.8	2.7	2.5	2.3	2.3	2.4	2.8	3.7	3.8
Gila	GiiaCliffs	42	GICL1	NM	33.22	108.25	2.1	1.9	1.6	1.3	1.4	1.2	2.1	2.0	1.8	1.6	1.8	2.2
Glacier	Glacier	72	GLAC1	MT	48.51	114.00	4.0	3.5	3.2	3.1	3.2	3.4	2.8	2.6	3.2	3.5	3.8	3.9
Glacier Peak	North Cascades	81	NOCA1	WA	48.21	121.04	4.2	3.7	3.4	3.8	2.9	3.2	2.9	3.1	3.3	3.9	4.4	4.4
Goat Rocks	White Pass	79	WHPA1	WA	46.54	121.48	4.3	3.8	3.4	4.2	2.8	3.4	3.0	3.2	3.1	3.8	4.4	4.6
Grand Canyon	Grand Canyon, Hance	48	GRCA2	AZ	35.97	111.98	2.4	2.3	1.9	1.5	1.4	1.2	1.4	1.7	1.6	1.6	1.9	2.3
Grand Teton	Yellowstone	66	YELL2	WY	43.68	110.73	2.6	2.4	2.2	2.1	2.1	1.8	1.5	1.5	1.7	2.0	2.4	2.6
Great Gulf	Great Gulf	4	GRGU1	NH	44.31	71.22	2.8	2.6	2.6	2.8	2.9	3.2	3.5	3.8	4.0	3.4	3.1	2.9
Great Sand Dunes	Great Sand Dunes	53	GRSA1	CO	37.73	105.52	2.4	2.3	2.0	1.9	1.9	1.8	1.9	2.3	2.2	1.9	2.4	2.4
Great Smoky Mountains	Great Smoky Mountains	10	GRSM1	TN	35.63	83.94	3.3	3.0	2.9	2.7	3.2	3.9	3.8	4.0	4.2	3.8	3.3	3.4
Guadalupe Mountains	Guadalupe Mountains	32	GUM01	TX	31.83	104.80	2.0	2.0	1.6	1.5	1.6	1.5	1.9	2.2	2.2	1.8	1.9	2.2
Haleakala	Haleakala	108	HALE1	HI	20.81	156.28	2.7	2.6	2.6	2.5	2.4	2.3	2.5	2.4	2.4	2.5	2.8	2.7
Hawaii Volcanoes	Hawaii Volcanoes	107	HAV01	HI	19.43	155.27	3.2	2.9	3.0	3.0	3.0	2.9	3.1	3.2	3.2	3.2	3.7	3.2
Hells Canyon	Hells Canyon	77	HECA1	OR	45.34	116.57	3.7	3.1	2.5	2.2	2.1	2.0	1.6	1.6	1.8	2.4	3.5	3.9
Hercules - Glade	Hercules - Glade	28	HEGL1	MO	36.69	92.90	3.2	2.9	2.7	2.7	3.3	3.3	3.3	3.3	3.4	3.1	3.1	3.3
Hoover	Hoover	97	HOOV1	CA	38.14	119.45	3.1	2.8	2.5	2.1	1.9	1.6	1.5	1.5	1.6	1.8	2.3	2.8
Isle Royale	Isle Royale	25	ISLE1	MI	47.99	88.83	3.1	2.5	2.7	2.4	2.2	2.6	3.0	3.2	3.8	2.7	3.3	3.3
James River Face	James River Face	7	JARI1	VA	37.62	79.48	2.8	2.6	2.7	2.4	3.0	3.3	3.4	3.7	3.6	3.2	2.8	3.0
Jarbidge	Jarbidge	68	JARB1	NV	41.89	115.43	3.0	2.6	2.1	2.1	2.2	2.2	1.6	1.4	1.4	1.6	2.4	2.8
John Muir	Kaiser	110	KAIS1	CA	37.39	118.84	2.9	2.6	2.4	2.1	1.9	1.7	1.7	1.7	1.7	1.9	2.2	2.6
Joshua Tree	Joshua Tree	101	JOSH1	CA	34.03	116.18	2.4	2.3	2.2	2.0	2.0	1.9	2.0	2.0	2.0	2.0	1.9	2.0
Joyce Kilmer - Slickrock	Great Smoky Mountains	10	GRSM1	TN	35.43	84.00	3.3	3.1	2.9	2.7	3.3	3.8	4.0	4.2	4.2	3.8	3.3	3.5
Kaiser	Kaiser	110	KAIS1	CA	37.28	119.18	3.0	2.7	2.5	2.1	1.9	1.7	1.6	1.7	1.7	1.9	2.3	2.7
Kalmiopsis	Kalmiopsis	89	KALM1	OR	42.27	123.93	4.5	3.9	3.8	3.5	3.5	3.3	3.2	3.2	3.3	3.6	4.4	4.3
Kings Canyon	Sequoia	98	SEQU1	CA	36.82	118.76	2.8	2.6	2.4	2.1	1.9	1.8	1.7	1.7	1.8	1.9	2.3	2.5
La Garita	Weminuche	55	WEMI1	CO	37.96	106.81	2.3	2.2	1.9	1.8	1.8	1.6	1.7	2.1	2.0	1.8	2.2	2.3
Lassen Volcanic	Lassen Volcanic	90	LAV01	CA	40.54	121.57	3.8	3.2	2.9	2.5	2.4	2.2	2.1	2.1	2.2	2.4	3.1	3.5
Lava Beds	Lava Beds	87	LABE1	CA	41.71	121.34	4.0	3.4	3.1	2.7	2.6	2.4	2.3	2.3	2.4	2.7	3.5	3.8
Linville Gorge	Linville Gorge	13	LIG01	NC	35.89	81.89	3.3	3.0	3.0	2.7	3.3	3.9	4.1	4.5	4.4	3.7	3.2	3.4
Lostwood	Lostwood	62	LOST1	ND	48.60	102.48	3.0	2.9	2.9	2.3	2.3	2.6	2.7	2.4	2.3	2.4	3.2	3.2
Lye Brook	Lye Brook	3	LYBR1	VT	43.15	73.12	2.7	2.6	2.6	2.6	2.8	3.0	3.3	3.6	3.7	3.3	2.9	2.8
Mammoth Cave	Mammoth Cave	9	MACA1	KY	37.22	86.07	3.4	3.1	2.9	2.6	3.2	3.5	3.7	3.9	3.9	3.4	3.2	3.5
Marble Mountain	Trinity	104	TRIN1	CA	41.52	123.21	4.4	3.8	3.7	3.3	3.4	3.2	3.2	3.2	3.2	3.4	4.1	4.2
Maroon Bells - Snowmass	White River	56	WHRI1	CO	39.15	106.82	2.2	2.1	2.0	2.0	2.1	1.7	1.9	2.2	2.1	1.8	2.1	2.1

APPENDIX C: Monthly Site-Specific f(RH) Values For All National 156 Federally Mandated Class I Areas (continued)

Table A-3 Monthly Site-Specific f(RH) Values for Each Mandatory Federal Class I Area, Based on the Centroid of the Area (Supplemental Information)

Class I Area	Site Name	Map ID	Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Mazatzal	Ike's Backbone	46	IKBA1	AZ	33.92	111.43	2.1	1.9	1.7	1.3	1.3	1.1	1.5	1.7	1.6	1.5	1.7	2.1
Medicine Lake	Medicine Lake	63	MELA1	MT	48.50	104.29	3.0	2.9	2.9	2.3	2.2	2.5	2.5	2.2	2.2	2.4	3.2	3.2
Mesa Verde	Mesa Verde	54	MEVE1	CO	37.20	108.49	2.5	2.3	1.9	1.5	1.5	1.3	1.6	2.0	1.9	1.7	2.1	2.3
Mingo	Mingo	26	MING1	MO	36.98	90.20	3.3	3.0	2.8	2.6	3.0	3.2	3.3	3.5	3.5	3.1	3.1	3.3
Mission Mountains	Monture	73	MONT1	MT	47.40	113.85	3.6	3.1	2.7	2.5	2.6	2.6	2.3	2.2	2.5	2.9	3.5	3.6
Mokelumne	Bliss	95	BLIS1	CA	38.58	120.03	3.2	2.8	2.4	2.0	1.9	1.6	1.5	1.6	1.7	1.9	2.4	2.9
Moosehorn	Moosehorn	2	MOOS1	ME	45.12	67.26	3.0	2.7	2.7	3.0	3.0	3.1	3.4	3.8	3.9	3.5	3.2	3.2
Mount Adams	White Pass	79	WHPA1	WA	46.19	121.50	4.3	3.8	3.4	4.4	2.9	3.5	3.1	3.3	3.1	3.9	4.5	4.6
Mount Baldy	Mount Baldy	43	BALD1	AZ	34.12	109.57	2.2	2.0	1.7	1.4	1.3	1.2	1.6	1.9	1.7	1.6	1.8	2.2
Mount Hood	Mount Hood	85	MOH01	OR	45.38	121.69	4.3	3.8	3.5	3.9	3.0	3.2	2.9	3.0	3.1	3.9	4.5	4.6
Mount Jefferson	Three Sisters	84	THSI1	OR	44.55	121.83	4.4	3.9	3.6	3.7	3.1	3.1	2.9	2.9	3.0	3.8	4.6	4.5
Mount Rainier	Mount Rainier	78	MORA1	WA	46.76	122.12	4.4	4.0	3.6	4.7	3.1	3.7	3.3	3.5	3.4	4.1	4.7	4.7
Mount Washington	Three Sisters	84	THSI1	OR	44.30	121.87	4.4	3.9	3.6	3.7	3.1	3.1	3.0	2.9	3.0	3.8	4.6	4.6
Mount Zirkel	Mount Zirkel	58	MOZI1	CO	40.55	106.70	2.2	2.2	2.0	2.1	2.2	1.9	1.7	1.9	2.0	1.9	2.1	2.1
Mountain Lakes	Crater Lake	86	CRLA1	OR	42.34	122.11	4.3	3.6	3.3	3.0	2.9	2.6	2.5	2.5	2.6	3.1	4.1	4.3
North Absaroka	North Absoraka	67	NOAB1	WY	44.77	109.78	2.4	2.3	2.2	2.2	2.1	1.9	1.7	1.6	1.8	2.0	2.4	2.4
North Cascades	North Cascades	81	NOCA1	WA	48.54	121.44	4.1	3.7	3.4	3.7	2.9	3.2	2.9	3.2	3.5	3.9	4.4	4.4
Okefenokee	Okefenokee	16	OKEF1	GA	30.74	82.13	3.5	3.2	3.1	3.0	3.6	3.7	3.7	4.1	4.0	3.8	3.5	3.6
Olympic	Olympic	83	OLYM1	WA	47.32	123.35	4.5	4.1	3.8	4.1	3.2	3.5	3.1	3.5	3.7	4.4	4.8	4.8
Otter Creek	Dolly Sods	8	DOS01	WV	39.00	79.65	3.0	2.8	2.8	2.6	3.2	3.5	3.7	4.1	4.0	3.3	3.0	3.1
Pasayten	Pasayten	82	PASA1	WA	48.85	120.52	4.2	3.7	3.4	3.7	2.9	3.2	2.9	3.2	3.3	3.9	4.4	4.5
Pecos	Wheeler Peak	35	WHPE1	NM	35.93	105.64	2.3	2.1	1.8	1.7	1.7	1.5	1.8	2.1	2.0	1.7	2.0	2.2
Petrified Forest	Petrified Forest	41	PEF01	AZ	35.08	109.77	2.4	2.2	1.7	1.4	1.3	1.2	1.5	1.8	1.7	1.6	1.9	2.3
Pine Mountain	Ike's Backbone	46	IKBA1	AZ	34.31	111.80	2.2	2.0	1.7	1.4	1.3	1.1	1.4	1.8	1.6	1.5	1.7	2.1
Pinnacles	Pinnacles	92	PINN1	CA	36.49	121.16	3.2	2.8	2.6	2.4	2.3	2.0	2.0	2.1	2.1	2.3	2.5	2.9
Point Reyes	Point Reyes	91	PORE1	CA	38.12	122.90	3.6	3.3	3.1	2.7	2.5	2.3	2.5	2.6	2.6	2.7	2.9	3.3
Presidential Range - Dry River	Great Gulf	4	GRGU1	NH	44.21	71.35	2.8	2.6	2.6	2.8	3.0	3.4	3.7	4.0	4.3	3.5	3.1	3.0
Rawah	Mount Zirkel	58	MOZI1	CO	40.70	105.94	2.1	2.1	2.0	2.1	2.3	2.0	1.8	2.0	2.0	1.9	2.1	2.0
Red Rock Lakes	Yellowstone	66	YELL2	WY	44.67	111.70	2.7	2.5	2.3	2.1	2.1	1.9	1.7	1.6	1.8	2.1	2.6	2.7
Redwood	Redwood	88	REDW1	CA	41.56	124.08	4.4	3.9	4.6	3.9	4.5	4.7	4.9	4.7	4.3	3.7	3.8	3.4
Rocky Mountain	Rocky Mountain	57	ROM01	CO	40.28	105.55	1.7	1.9	1.9	2.1	2.3	2.0	1.8	2.0	1.9	1.8	1.8	1.7
Roosevelt Campobello	Moosehorn	2	MOOS1	ME	44.88	66.95	3.0	2.7	2.7	3.0	3.0	3.1	3.4	3.8	3.9	3.5	3.3	3.2
Saguaro	Saguaro	40	SAGU1	AZ	32.25	110.73	1.8	1.6	1.4	1.1	1.1	1.1	1.4	1.8	1.6	1.4	1.6	2.1
Saint Marks	Saint Marks	17	SAMA1	FL	30.12	84.08	3.7	3.4	3.4	3.4	3.5	4.0	4.1	4.4	4.2	3.8	3.7	3.8
Salt Creek	Salt Creek	36	SACR1	NM	33.61	104.37	2.1	1.9	1.5	1.5	1.7	1.6	1.8	2.0	2.1	1.8	1.8	2.1
San Gabriel	San Gabriel	93	SAGA1	CA	34.27	117.94	2.5	2.5	2.4	2.2	2.2	2.1	2.2	2.2	2.2	2.3	2.1	2.2
San Gorgonio	San Gorgonio	99	SAG01	CA	34.18	116.90	2.7	2.8	2.6	2.3	2.2	1.9	1.8	1.9	1.9	1.9	1.9	2.2
San Jacinto	San Gorgonio	99	SAG01	CA	33.75	116.65	2.5	2.4	2.4	2.2	2.1	2.0	2.1	2.1	2.1	2.1	2.0	2.1
San Pedro Parks	San Pedro Parks	34	SAPE1	NM	36.11	106.81	2.3	2.1	1.8	1.6	1.6	1.4	1.7	2.0	1.9	1.7	2.1	2.2
San Rafael	San Rafael	94	RAFA1	CA	34.78	119.83	2.8	2.7	2.7	2.4	2.3	2.3	2.5	2.5	2.4	2.5	2.3	2.5

APPENDIX C: Monthly Site-Specific f(RH) Values For All National 156 Federally Mandated Class I Areas (continued)

Table A-3 Monthly Site-Specific f(RH) Values for Each Mandatory Federal Class I Area,

Based on the Centroid of the Area (Supplemental Information)

Class I Area	Site Name	Map ID	Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Sawtooth	Sawtooth	70	SAWT1	ID	44.18	114.93	3.3	2.9	2.3	2.0	2.0	1.8	1.4	1.4	1.5	2.0	2.9	3.3
Scapegoat	Monture	73	MONT1	MT	47.17	112.73	3.2	2.8	2.6	2.4	2.5	2.4	2.1	2.0	2.3	2.6	3.1	3.1
Selway - Bitterroot	Sula	71	SULA1	MT	45.86	114.00	3.5	3.0	2.6	2.3	2.4	2.3	1.9	1.9	2.1	2.6	3.3	3.5
Seney	Seney	22	SENE1	MI	46.26	86.03	3.3	2.8	2.9	2.7	2.6	3.1	3.6	4.0	4.1	3.4	3.6	3.5
Sequoia	Sequoia	98	SEQU1	CA	36.50	118.82	2.5	2.4	2.4	2.2	1.9	1.8	1.7	1.6	1.8	1.9	2.3	2.3
Shenandoah	Shenandoah	6	SHEN1	VA	38.52	78.44	3.1	2.8	2.8	2.5	3.1	3.4	3.5	3.9	3.9	3.2	3.0	3.1
Shining Rock	Shining Rock	11	SHRO1	NC	35.39	82.78	3.3	3.0	2.9	2.7	3.4	3.9	4.1	4.5	4.4	3.8	3.3	3.4
Sierra Ancha	Sierra Ancha	45	SIAN1	AZ	33.82	110.88	2.1	2.0	1.7	1.3	1.3	1.1	1.5	1.8	1.6	1.5	1.7	2.1
Simeonof	Simeonof	105	SIME1	AK	54.92	159.28	4.3	4.1	3.6	3.9	3.9	4.3	5.0	5.2	4.5	3.8	4.0	4.3
Sipsey	Sipsey	21	SIPS1	AL	34.34	87.34	3.4	3.1	2.9	2.8	3.3	3.7	3.9	3.9	3.9	3.6	3.3	3.4
South Warner	Lava Beds	87	LABE1	CA	41.33	120.20	3.6	3.1	2.7	2.4	2.3	2.1	1.9	1.9	2.0	2.3	3.1	3.4
Strawberry Mountain	Starkey	76	STAR1	OR	44.30	118.73	3.9	3.3	2.8	2.9	2.3	2.4	2.0	2.0	1.9	2.6	3.7	4.1
Superstition	Tonto	44	TONT1	AZ	33.63	111.10	2.1	1.9	1.6	1.3	1.3	1.1	1.5	1.7	1.6	1.5	1.7	2.1
Swanquarter	Swanquarter	14	SWAN 1	NC	35.31	76.28	2.9	2.7	2.6	2.5	2.9	3.2	3.4	3.5	3.4	3.1	2.8	2.9
Sycamore Canyon	Sycamore Canyon	47	SYCA1	AZ	34.03	116.18	2.4	2.3	2.2	2.0	2.0	1.9	2.0	2.0	2.0	2.0	1.9	2.0
Teton	Yellowstone	66	YELL2	WY	44.09	110.18	2.5	2.4	22	2.1	2.1	1.9	1.6	1.5	1.7	2.0	2.4	2.5
Theodore Roosevelt	Theodore	61	THRO1	NO	47.30	104.00	2.9	2.8	2.8	2.3	2.3	2.5	2.4	2.2	2.2	2.3	3.0	3.0
Thousand Lakes	Lassen Volcanic	90	LAVO1	CA	40.70	121.58	3.8	3.2	2.9	2.5	2.4	2.2	2.1	2.1	2.2	2.4	3.1	3.5
Three Sisters	Three Sisters	84	THSI1	OR	44.29	122.04	4.5	4.0	3.6	3.7	3.1	3.1	3.0	2.9	3.0	3.8	4.6	4.6
Tuxedni	Tuxedni	103	TUXE1	AK	60.15	152.60	3.5	3.3	2.9	2.7	2.7	2.9	3.6	4.0	3.9	3.5	3.5	3.7
UL Bend	UL Bend	64	ULBE1	MT	47.55	107.87	2.7	2.5	2.5	2.3	2.2	2.2	2.0	1.8	1.9	. 2.2	2.7	2.7
Upper Buffalo	Upper Buffalo	27	UPBU1	AR	35.83	93.21	3.3	3.0	2.7	2.8	3.4	3.4	3.4	3.4	3.6	3.3	3.2	3.3
Ventana	Pinnacles	92	PINN1	CA	36.22	121.59	3.2	2.9	2.8	2.4	2.3	2.1	2.2	2.3	2.2	2.4	2.5	2.9
Virgin Islands (b)	Virgin Islands	106	VIIS1	VI	18.33	64.79												
Voyageurs	Voyageurs	24	VOYA2	MN	48.59	93.17	2.8	2.4	2.4	2.3	2.3	3.1	2.7	3.0	3.2	2.6	2.9	2.8
Washakie	North Absoraka	67	NOAB1	WY	43.95	109.59	2.5	2.3	2.2	2.1	2.1	1.8	1.6	1.5	1.8	2.0	2.4	2.5
Weminuche	Weminuche	55	WEMI1	CO	37.65	107.80	2.4	2.2	1.9	1.7	1.7	1.5	1.6	2.0	1.9	1.7	2.1	2.3
West Elk	White River	56	WHRI1	CO	38.69	107.19	2.3	2.2	1.9	1.9	1.9	1.7	1.8	2.1	2.0	1.8	2.1	2.2
Wheeler Peak	Wheeler Peak	35	WHPE1	NM	36.57	105.42	2.3	2.2	1.9	1.8	1.8	1.6	1.8	2.2	2.1	1.8	2.2	2.3
White Mountain	White Mountain	37	WHIT1	NM	33.49	105.83	2.1	1.9	1.6	1.5	1.5	1.4	1.8	2.0	2.0	1.7	1.8	2.1
Wichita Mountains	Wichita Mountains	30	WIMO1	OK	34.74	98.59	2.7	2.6	2.4	2.4	3.0	2.7	2.3	2.5	2.9	2.6	2.7	2.8
Wind Cave	Wind Cave	60	WICA1	SO	43.55	103.48	2.5	'2.5	2.5	2.5	2.7	2.5	2.3	2.3	2.2	2.2	2.6	2.6
Wolf Island	Okefenokee	16	OKEF1	GA	31.31	81.30	3.4	3.1	3.1	3.0	3.3	3.7	3.7	4.1	4.0	3.7	3.5	3.5
Yellowstone	Yellowstone	66	YELL2	WY	44.55	110.40	2.5	2.4	2.3	2.2	2.2	1.9	1.7	1.6	1.8	2.1	2.5	2.5
Yolla Bolly - Middle Eel	Trinity	104	TRIN1	CA	40.11	122.96	4.0	3.4	3.1	2.8	2.7	2.5	2.4	2.5	2.6	2.7	3.3	3.6
Yosemite	Yosemite	96	YOSE1	CA	37.71	119.70	3.3	3.0	2.8	2.3	2.1	1.8	1.5	1.5	1.5	1.8	2.4	2.8
Zion	Zion	51	ZION1	UT	37.25	113.01	2.7	2.4	2.0	1.6	1.5	1.3	1.2	1.4	1.4	1.6	2.0	2.4

a: No particulate matter sampling or visibility monitoring is conducted in the Bering Sea Wilderness.

b: *f(RH)* values for Virgin Islands National Park were not calculated because of the limited RH data available.

APPENDIX D:

Default Visibility Values For 156 Federally Mandated Class I Areas: Annual Natural Background, and 20% Best and Worse Days[10]

[10]. EPA. 2003. Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program. EPA-454/B-03-005. U.S. Environment Protection Agency. Office of Air Quality Planning and Standards. Emissions, Monitoring and Analysis Division. Air Quality Trends Analysis Group. Research Triangle Park, NC.

APPENDIX D: Default Visibility Values For 156 Federally Mandated Class I Areas: Annual Natural Background, and 20% Best and Worse Days

Default Natural b_{ext}, *dv*, and 10th and 90th Percentile

***dv* Values at All Mandatory Federal Class I Areas**

Mandatory Federal Class I Area	State	Lat.	Long.	bext (Mm-1)	Ann. Avg. (dv)	Best Days (dv) (a)	Worst Days (dv) (a)
Acadia NP	ME	44.35	-68.24	21.40	7.61	3.77	11.45
Agua Tibia Wilderness	CA	33.42	-116.99	15.86	4.61	2.05	7.17
Alpine Lake Wilderness	WA	47.55	-121.16	16.99	5.30	2.74	7.86
Anaconda-Pintler Wilderness	MT	45.95	-113.5	16.03	4.72	2.16	7.28
Arches NP	UT	38.73	-109.58	15.58	4.43	1.87	6.99
Badlands NP	SD	43.81	-102.36	16.06	4.74	2.18	7.30
Bandelier NM	NM	35.79	-106.34	15.62	4.46	1.90	7.02
Bering Sea	AK	60.46	-172.75				
Big Bend NP	TX	29.33	-103.31	15.48	4.37	1.81	6.93
Black Canyon of the Gunnison NM	CO	38.57	-107.75	15.68	4.50	1.94	7.06
Bob Marshall Wilderness	MT	47.68	-113.23	16.17	4.80	2.24	7.36
Bosque del Apache	NM	33.79	-106.85	15.54	4.41	1.85	6.97
Boundary Waters Canoe Area	MN	48.06	-91.43	20.89	7.37	3.53	11.21
Breton	LA	29.87	-88.82	21.57	7.69	3.85	11.53
Bridger Wilderness	WY	42.99	-109.49	15.71	4.52	1.96	7.08
Brigantine	NJ	39.49	-74.39	21.05	7.44	3.60	11.28
Bryce Canyon NP	UT	37.57	-112.17	15.58	4.43	1.87	6.99
Cabinet Mountains Wilderness	MT	48.18	-115.68	16.27	4.87	2.31	7.43
Caney Creek Wilderness	AR	34.41	-94.08	21.14	7.49	3.65	11.33
Canyonlands NP	UT	38.23	-109.91	15.60	4.45	1.89	7.01
Cape Romain	SC	32.99	-79.49	21.22	7.52	3.68	11.36
Capitol Reef NP	UT	38.06	-111.15	15.63	4.47	1.91	7.03
Caribou Wilderness	CA	40.49	-121.21	16.05	4.73	2.17	7.29
Carlsbad Caverns NP	NM	32.12	-104.59	15.61	4.46	1.90	7.02
Chassahowitzka	FL	28.69	-82.66	21.46	7.63	3.79	11.47
Chiricahua NM	AZ	32.01	-109.34	15.47	4.36	1.80	6.92
Chiricahua Wilderness	AZ	31.86	-109.28	15.45	4.35	1.79	6.91
Cohutta Wilderness	GA	34.93	-84.57	21.39	7.60	3.76	11.44
Crater Lake NP	OR	42.92	-122.13	16.74	5.15	2.59	7.71
Craters of the Moon NM	ID	43.39	-113.54	15.80	4.57	2.01	7.13
Cucamonga Wilderness	CA	34.24	-117.59	15.85	4.61	2.05	7.17
Denali Preserve NP	AK	63.31	-151.19	16.27	4.86	2.30	7.42
Desolation Wilderness	CA	38.9	-120.17	15.80	4.57	2.01	7.13
Diamond Peak Wilderness	OR	43.53	-122.1	16.84	5.21	2.65	7.77
Dolly Sods Wilderness	VW	39	-79.37	21.13	7.48	3.64	11.32
Dome Land Wilderness	CA	35.84	-118.23	15.70	4.51	1.95	7.07
Eagle Cap Wilderness	OR	45.22	-117.37	16.12	4.78	2.22	7.34

APPENDIX D: Default Visibility Values For 156 Federally Mandated Class I Areas: Annual Natural Background, and 20% Best and Worse Days (continued)

Default Natural b_{ext}, *dv*, and 10th and 90th Percentile

***dv* Values at All Mandatory Federal Class I Areas**

Mandatory Federal Class I Area	State	Lat.	Long.	bext (Mm-1)	Ann. Avg. (dv)	Best Days (dv) (a)	Worst Days (dv) (a)
Eagles Nest Wilderness	CO	39.67	-106.29	15.72	4.52	1.96	7.08
Emigrant Wilderness	CA	38.18	-119.77	15.81	4.58	2.02	7.14
Everglades NP	FL	25.35	-80.98	20.77	7.31	3.47	11.15
Fitzpatrick Wilderness	WY	43.24	-109.6	15.73	4.53	1.97	7.09
Flat Tops Wilderness	CO	39.95	-107.3	15.70	4.51	1.95	7.07
Galiuro Wilderness	AZ	32.6	-110.39	15.40	4.32	1.76	6.88
Gates of the Mountains Wilderness	MT	46.86	-111.82	15.93	4.66	2.10	7.22
Gearhart Mountain Wilderness	OR	42.51	-120.86	16.33	4.90	2.34	7.46
Gila Wilderness	NM	33.21	-108.47	15.51	4.39	1.83	6.95
Glacier NP	MT	48.64	-113.84	16.48	5.00	2.44	7.56
Glacier Peak Wilderness	WA	48.21	-121	16.88	5.24	2.68	7.80
Goat Rocks Wilderness	WA	46.52	-121.47	16.93	5.26	2.70	7.82
Grand Canyon NP	AZ	36.3	-112.79	15.51	4.39	1.83	6.95
Grand Teton NP	WY	43.82	-110.71	15.74	4.53	1.97	7.09
Great Gulf Wilderness	NH	44.3	-71.28	21.10	7.47	3.63	11.31
Great Sand Dunes NM	CO	37.77	-105.57	15.74	4.54	1.98	7.10
Great Smoky Mountains NP	TN	35.6	-83.52	21.39	7.60	3.76	11.44
Guadalupe Mountains NP	TX	31.91	-104.85	15.64	4.47	1.91	7.03
Haleakala NP	HI	20.71	-156.16	16.02	4.71	2.15	7.27
Hawaii Volcanoes NP	HI	19.41	-155.34	16.33	4.91	2.35	7.47
Hells Canyon Wilderness	OR	45.54	-116.59	16.09	4.76	2.20	7.32
Hercules-Glades Wilderness	MO	36.68	-92.9	21.03	7.43	3.59	11.27
Hoover Wilderness	CA	38.11	-119.37	15.78	4.56	2.00	7.12
Isle Royale NP	MI	48.01	-88.83	20.91	7.38	3.54	11.22
James River Face Wilderness	VA	37.59	-79.44	20.96	7.40	3.56	11.24
Jarbidge Wilderness	NV	41.77	-115.35	15.75	4.54	1.98	7.10
John Muir Wilderness	CA	36.97	-118.88	15.80	4.58	2.02	7.14
Joshua Tree NM	CA	33.92	-115.88	15.72	4.52	1.96	7.08
Joyce-Kilmer-Slickrock Wilderness	TN	35.44	-83.99	21.40	7.61	3.77	11.45
Kaiser Wilderness	CA	37.28	-119.17	15.80	4.57	2.01	7.13
Kalmiopsis Wilderness	OR	42.26	-123.92	16.74	5.15	2.59	7.71
Kings Canyon NP	CA	36.92	-118.61	15.79	4.57	2.01	7.13
La Garita Wilderness	CO	37.95	-106.83	15.69	4.50	1.94	7.06
Lassen Volcanic NP	CA	40.49	-121.41	16.08	4.75	2.19	7.31
Lava Beds NM	CA	41.76	-121.52	16.37	4.93	2.37	7.49
Linville Gorge Wilderness	NC	35.88	-81.9	21.36	7.59	3.75	11.43
Lostwood	ND	48.59	-102.46	16.11	4.77	2.21	7.33

APPENDIX D: Default Visibility Values For 156 Federally Mandated Class I Areas: Annual Natural Background, and 20% Best and Worse Day (continued)

Default Natural b_{ext}, *dv*, and 10th and 90th Percentile

***dv* Values at All Mandatory Federal Class I Areas**

Mandatory Federal Class I Area	State	Lat.	Long.	bext (Mm-1)	Ann. Avg. (dv)	Best Days (dv) (a)	Worst Days (dv) (a)
Lye Brook Wilderness	VT	43.13	-73.02	20.99	7.41	3.57	11.25
Mamrnoth Cave NP	KY	37.2	-86.15	21.58	7.69	3.85	11.53
Marble Mountain Wilderness	CA	41.51	-123.21	16.65	5.10	2.54	7.66
Maroon Bells-Snowmass Wilderness	CO	39.1	-107.02	15.70	4.51	1.95	7.07
Mazatzal Wilderness	AZ	34.13	-111.56	15.44	4.35	1.79	6.91
Medicine Lake	MT	48.49	-104.35	16.07	4.74	2.18	7.30
Mesa Verde NP	CO	37.25	-108.45	15.73	4.53	1.97	7.09
Minarets Wilderness	CA	37.74	-119.19	15.78	4.56	2.00	7.12
Mingo	MO	37	-90.19	21.03	7.43	3.59	11.27
Mission Mountains Wilderness	MT	47.48	-113.87	16.21	4.83	2.27	7.39
Mokelumne Wilderness	CA	38.57	-120.06	15.80	4.58	2.02	7.14
Moosehorn	ME	45.09	-67.29	21.22	7.52	3.68	11.36
Mount Adams Wilderness	WA	46.2	-121.49	16.86	5.22	2.66	7.78
Mount Baldy Wilderness	AZ	33.95	-109.54	15.51	4.39	1.83	6.95
Mount Hood Wilderness	OR	45.37	-121.73	16.83	5.21	2.65	7.77
Mount Jefferson Wilderness	OR	44.61	-121.84	16.91	. 5.25	2.69	7.81
Mount Rainier NP	WA	46.86	-121.72	17.05	5.34	2.78	7.90
Mount Washington Wilderness	OR	44.3	-121.88	17.03	5.33	2.77	7.89
Mount Zirkel Wilderness	CO	40.75	-106.68	15.71	4.52	1.96	7.08
Mountain Lakes Wilderness	OR	42.33	-122.11	16.50	5.01	2.45	7.57
North Absaroka Wilderness	\NY	44.74	-109.8	15.74	4.53	1.97	7.09
North Cascades NP	WA	48.83	-121.35	16.86	5.22	2.66	7.78
Okefenokee	GA	30.82	-82.33	21.41	7.61	3.77	11.45
Olympic NP	WA	47.77	-123.74	17.02	5.32	2.76	7.88
Otter Creek Wilderness	WV	38.99	-79.65	21.14	7.49	3.65	11.33
Pasayten Wilderness	WA	48.89	-120.44	16.84	5.21	2.65	7.77
Pecos Wilderness	NM	35.9	-105.62	15.65	4.48	1.92	7.04
Petrified Forest NP	AZ	34.99	-109.79	15.54	4.41	1.85	6.97
Pine Mountain Wilderness	AZ	34.31	-111.8	15.47	4.36	1.80	6.92
Pinnacles NM	CA	36.48	-121.19	16.12	4.78	2.22	7.34
Point Reyes NS	CA	38.06	-122.9	16.20	4.83	2.27	7.39
Presidential Range-Dry River Wilderness	NH	44.2	-71.34	21.15	7.49	3.65	11.33
Rainbow Lake Wilderness	WI	46.42	-91.31	20.99	7.42	3.58	11.26
Rawah Wilderness	CO	40.69	-105.95	15.72	4.52	1.96	7.08
Red Rock Lakes	MT	44.64	-111.78	15.81	4.58	2.02	7.14
Redwood NP	CA	41.44	-124.03	16.90	5.25	2.69	7.81
Rocky Mountain NP	CO	40.35	-105.7	15.67	4.49	1.93	7.05

APPENDIX D: Default Visibility Values For 156 Federally Mandated Class I Areas: Annual Natural Background, and 20% Best and Worse Days (continued)

Default Natural b_{ext}, *dv*, and 10th and 90th Percentile
***dv* Values at All Mandatory Federal Class I Areas**

Mandatory Federal Class I Area	State	Lat.	Long.	bext (Mm-1)	Ann. Avg. (dv)	Best Days (dv) (a)	Worst Days (dv) (a)
Roosevelt Campobello International Park	ME	44.85	-66.94	21.22	7.52	3.68	11.36
Saguaro NM	AZ	32.17	-110.61	15.35	4.28	1.72	6.84
Salt Creek	NM	33.6	-104.41	15.58	4.43	1.87	6.99
San Gabriel Wilderness	CA	34.27	-117.94	15.86	4.61	2.05	7.17
San Gorgonio Wilderness	CA	34.12	-116.84	15.74	4.54	1.98	7.10
San Jacinto Wilderness	CA	33.75	-116.64	15.78	4.56	2.00	7.12
San Pedro Parks Wilderness	NM	36.11	-106.81	15.63	4.47	1.91	7.03
San Rafael Wilderness	CA	34.76	-119.81	16.03	4.72	2.16	7.28
Sawtooth Wilderness	ID	43.99	-115.06	15.82	4.59	2.03	7.15
Scapegoat Wilderness	MT	47.16	-112.74	16.05	4.73	2.17	7.29
Selway-Bitterroot Wilderness	ID	46.12	-114.86	16.09	4.76	2.20	7.32
Seney	MI	46.25	-86.09	21.23	7.53	3.69	11.37
Sequoia NP	CA	36.51	-118.56	15.79	4.57	2.01	7.13
Shenandoah NP	VA	38.47	-78.49	20.98	7.41	3.57	11.25
Shining Rock Wilderness	NC	35.38	-82.85	21.40	7.61	3.77	11.45
Sierra Ancha Wilderness	AZ	33.85	-110.9	15.46	4.36	1.80	6.92
Simeonof	AK	54.91	-159.28	17.21	5.43	2.87	7.99
Sipsey Wilderness	AL	34.32	-87.44	21.28	7.55	3.71	11.39
South Warner Wilderness	CA	41.31	-120.2	16.09	4.76	2.20	7.32
St. Marks	FL	30.11	-84.15	21.54	7.67	3.83	11.51
Strawberry Mountain Wilderness	OR	44.29	-118.74	16.37	4.93	2.37	7.49
Superstition Wilderness	AZ	33.5	-111.27	15.40	4.32	1.76	6.88
Swanquarter	NC	35.39	-76.39	20.91	7.38	3.54	11.22
Sycamore Canyon Wilderness	AZ	35.01	-112.09	15.53	4.40	1.84	6.96
Teton Wilderness	\NY	44.04	-110.17	15.74	4.53	1.97	7.09
Theodore Roosevelt NP	ND	46.96	-103.46	16.08	4.75	2.19	7.31
Thousand Lakes Wilderness	CA	40.7	-121.58	16.10	4.76	2.20	7.32
Three Sisters Wilderness	OR	44.04	-121.91	17.01	5.31	2.75	7.87
Tuxedni	AK	60.14	-152.61	16.58	5.06	2.50	7.62
UL Bend	MT	47.54	-107.89	15.87	4.62	2.06	7.18
Upper Buffalo Wilderness	AR	36.17	-92.41	21.04	7.44	3.60	11.28
Ventana Wilderness	CA	36.21	-121.6	16.09	4.76	2.20	7.32
Virgin Islands NP (b)	VI	18.35	-64.74				
Voyageurs NP	MN	48.47	-92.8	20.64	7.25	3.41	11.09
Washakie Wilderness	\NY	44.1	-109.57	15.73	4.53	1.97	7.09
Weminuche Wilderness	CO	37.61	-107.25	15.68	4.50	1.94	7.06
West Elk Wilderness	CO	38.75	-107.21	15.71	4.51	1.95	7.07

APPENDIX D: Default Visibility Values For 156 Federally Mandated Class I Areas: Annual Natural Background, and 20% Best and Worse Days (continued)

Default Natural b_{ext}, *dv*, and 10th and 90th Percentile *dv* Values at All Mandatory Federal Class I Areas

Mandatory Federal Class I Area	State	Lat.	Long.	bext (Mm-1)	Ann. Avg. (dv)	Best Days (dv) (a)	Worst Days (dv) (a)
Wheeler Peak Wilderness	NM	36.57	-105.4	15.70	4.51	1.95	7.07
White Mountain Wilderness	NM	33.48	-105.85	15.56	4.42	1.86	6.98
Wichita Mountains	OK	34.75	-98.65	20.60	7.23	3.39	11.07
Wind Cave NP	SO	43.58	-103.47	15.97	4.68	2.12	7.24
Wolf Island	GA	31.33	-81.3	21.33	7.58	3.74	11.42
Yellowstone NP	WY	44.63	-110.51	15.77	4.56	2.00	7.12
Yolla Bolly Middle Eel Wilderness	CA	40.09	-122.96	16.25	4.85	2.29	7.41
Yosemite NP	CA	37.85	-119.54	15.81	4.58	2.02	7.14
Zion NP	UT	37.32	-113.04	15.56	4.42	1.86	6.98

(a) Values for the best and worst days are estimated from a statistical approach described in Section 2.6 of this document.
(b) *f(RH)* values for Virgin Islands National Park were not calculated because of the limited RH data available. As such no estimates for Natural Visibility Conditions are presented at this time.

APPENDIX E:

20% Best Days Aerosol Concentrations For 14 Significant Federally Mandated Class I Areas Using Current IMPROVE Reconstructed Light Extinction Equation

APPENDIX E: 20% Best Days Aerosol Concentrations For 14 Significant Federally Mandated Class I Areas Using Current IMPROVE Reconstructed Light Extinction Equation

Component	Average Annual Natural Background West	Class I Area 20% Best Visibility Days						
		Anaconda-Pintler WA[a]	Bob Marshall WA	Cabinet Mountains WA	Gates of the Mountains WA	Glacier National Park NP[b]	Medicine Lake WA	Mission Mountains WA
Ammonium Sulfate (μg/m^3)	0.12	0.048	0.048	0.049	0.046	0.050	0.048	0.049
Ammonium Nitrate (μg/m^3)	0.10	0.040	0.040	0.041	0.038	0.042	0.040	0.041
Organic Carbon Mass (μg/m^3)	0.47	0.186	0.188	0.193	0.180	0.197	0.188	0.192
Elemental Carbon (μg/m^3)	0.02	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Soil (Fine) (μg/m^3)	0.50	0.198	0.200	0.205	0.191	0.209	0.199	0.204
Coarse Mass (μg/m^3)	3.00	1.190	1.199	1.229	1.148	1.256	1.197	1.223
Total Fine (μg/m^3)	1.21	0.480	0.484	0.496	0.463	0.506	0.483	0.494
Total Coarse (μg/m^3)	3.00	1.190	1.199	1.229	1.148	1.256	1.197	1.223
Grand Total (μg/m^3)	4.21	1.670	1.683	1.725	1.611	1.762	1.680	1.717
Annual f(RH)	2.60[c]	2.57	2.88	2.98	2.63	3.35	2.63	2.84
b_{ext} (Mm^{-1})[d]	16.10 (Estimated)	12.41	12.51	12.60	12.34	12.76	12.44	12.55
Visibility (dv)[e]	4.762 (Estimated)	2.159	2.239	2.311	2.103	2.437	2.183	2.271

APPENDIX E: 20% Best Days Aerosol Concentrations For 14 Significant Federally Mandated Class I Areas Using Current IMPROVE Reconstructed Light Extinction Equation (continued)

Component	Average Annual Natural Background West	Class I Area 20% Best Visibility Days						
		Red Rock Lakes WA	Scapegoat WA	Selway-Bitterroot WA MT/WY[f]	U.L. Bend WA	Yellowstone NP MT/WY[g]	North Absaroka WA – WY[h]	Theodore Roosevelt NP – ND[i]
Ammonium Sulfate (μg/m^3)	0.12	0.046	0.048	0.048	0.047	0.046	0.045	0.048
Ammonium Nitrate (μg/m^3)	0.10	0.038	0.040	0.040	0.039	0.038	0.038	0.040
Organic Carbon Mass (μg/m^3)	0.47	0.181	0.187	0.189	0.182	0.179	0.178	0.190
Elemental Carbon (μg/m^3)	0.02	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Soil (Fine) (μg/m^3)	0.50	0.192	0.199	0.201	0.194	0.191	0.189	0.202
Coarse Mass (μg/m^3)	3.00	1.155	1.192	1.208	1.163	1.145	1.137	1.211
Total Fine (μg/m^3)	1.21	0.465	0.482	0.486	0.470	0.462	0.458	0.488
Total Coarse (μg/m^3)	3.00	1.155	1.192	1.208	1.163	1.145	1.137	1.211
Grand Total (μg/m^3)	4.21	1.620	1.674	1.694	1.633	1.607	1.595	1.699
Annual f(RH)	2.60[c]	2.18	2.59	2.62	2.31	2.14	2.08	2.56
b_{ext} (Mm^{-1})[d]	16.10 (Estimated)	12.24	12.42	12.46	12.29	12.21	12.18	12.45
Visibility (dv)[e]	4.762 (Estimated)	2.021	2.167	2.199	2.062	1.997	1.972	2.191

a. WA = Wilderness Area

[b.] NP = National Park.
[c.] The f(RH), the relative humidity adjustment factor, for the West average annual natural background category was calculated from the f(RH) average values of the fourteen Class I areas.
[d.] Mm^{-1} = Megameters.
[e.] dv = deciviews.
[f.] The f(RH), the relative humidity adjustment factor, for the Selway-Bitterroot WA represents the wilderness area in both Montana and Wyoming.
[g.] The f(RH), the relative humidity adjustment factor, for the Yellowstone NP represents the national parks in both Montana and Wyoming.
[h.] WY = Wyoming.
[i.] ND = North Dakota.